# 1987

# Minnesota Pesticide Recommendations and Applied Research Reports

## and

## Proceedings of the 1986 Soils, Fertilizer and Agricultural Pesticides Short Course, December 9-10, 1986

**Prepared by: Extention Specialists
in Agronomy, Entomology,
Plant Pathology and Soils**

**Minnesota Extention Service
University of Minnesota**

**OSP 9-1 Minnesota Extention Service**

# 1987 MINNESOTA PESTICIDE RECOMMENDATIONS
# AND APPLIED RESEARCH REPORTS

## and PROCEEDINGS OF THE 1986 SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES SHORT COURSE, DECEMBER 9-10, 1986

Office of Special Programs Educational Series 9-1

Prepared by Extension Specialists in
Agronomy, Entomology, Plant Pathology and Soils

Published by
Office of Special Programs
University of Minnesota
405 Coffey Hall
1420 Eckles Avenue
St. Paul, Minnesota 55108

December 9, 1986

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# ROOTS, TILLAGE AND NUTRIENT UPTAKE

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While most of us are quite familiar with the growth and development of the above ground parts of corn and soybeans, few of us probably are as familiar with how the root systems of these crops grow. This is understandable since looking at plant roots requires more effort than looking at plant shoots. In fact, very little crop production research is done which looks at the effects of agronomic treatments on both shoots and roots.

The overall objective of this paper is to look at a small part of the research on roots and production practices and try to develop a general understanding of plant roots and how they grow.

Two specific objectives are:

1. To show how the corn root system develops over the course of a growing season and how root growth relates to vegetative growth and nutrient uptake.

2. To illustrate some of the effects of management practices such as reducing tillage, on root growth and how this might impact yield.

Corn growth and development - above and below ground.

Corn is a grass, and has a fibrous type root system. When a corn seed germinates, the radicle, or primary root, elongates and breaks the seed coat. It is followed shortly by the coleoptile which surrounds the shoot and then 2 to 5 seminal roots (Figure 1). This initial seminal root system anchors the young plant and absorbs water and nutrients for the first week or two. Within a few days after emergence of the coleoptile and first leaves from the soil, a second or nodal root system begins to develop from the crown or growing point (Figure 2).

The nodal root system rapidly develops and becomes the dominant root system in just a few days. Normally within a month of emergence, the radical and seminal roots die. All of the remaining roots develop from the crownal nodes. As internodes elongate, and the growing point moves above ground, roots which develop above the soil surface are referred to as brace roots.

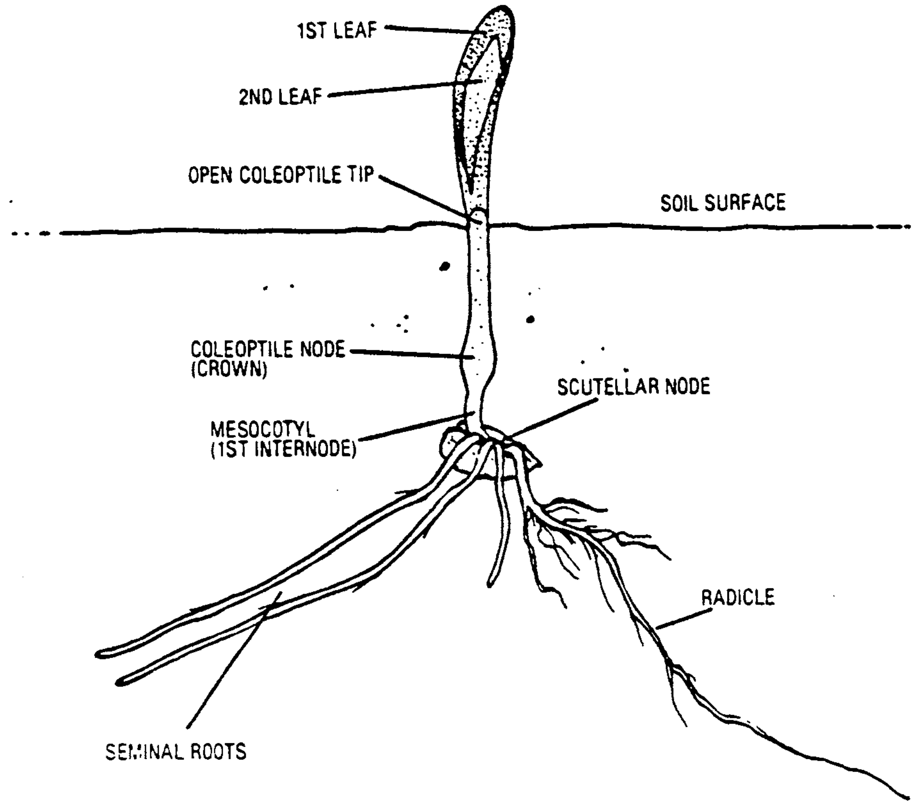


Figure 1. An Emerging Corn Seedling

In Table 1 is some data collected at Purdue which illustrates the relationship between shoot growth, root growth and the nutrient content of the plant at various times during the growing season. The hybrid used, P3369A, was a full season hybrid for central Indiana, requiring about 2800 "heat units" (growing degree days base 50) to reach maturity. At seeding, (21,700 plants per acre) 14 lbs of dry matter was planted. Twenty one days later dry weight had increased to 29 lb/acre. At that point, the 4 to 5 leaf stage, there were 54 miles of roots per acre, almost all in the top foot of soil. During this first 21 days, those 54 miles of roots took up about three quarters of a pound of N and K, and an eighth of a pound of P. Over the next 50 days, as the plant completed its vegetative growth and started to tassel, over 9,000 pounds of stover was produced per acre, and the root system increased from 54 miles of roots, all in the top foot, to 32,000 miles of roots per acre, going down 3 feet where dense glacial till stopped further growth.

At this point, 71 days after planting (July 12), the roots had taken up 73% of the N, 74% of the P and 85% of the K, which would be used by the plant. In addition, a major change occurred in the growth of the plant. A shift from vegetative growth to reproductive growth was occurring. Over the next three weeks, growth was concentrated in the developing ear. The root system reached its maximum size at silking with over 38,000 miles of roots per acre, and was maintained at that level for about two weeks after silking, or until the late blister/early milk stage. During these early stages of ear development, nutrient uptake slowed as the plant shifted gears from producing leaves to producing grain. Also, the rate of dry matter production slowed as this shift occurred.

Table 1. Shoot weight, root weight and nutrient content of corn at various stages during the growing season.

| Growth Stage days after planting | Shoot weight lb/acre | Root length miles/acre | Nutrient Content N | P | K |
|---|---|---|---|---|---|
| | | | | lb/acre | |
| Seeding | 14 | 0 | 0.2 | 0.04 | 0.03 |
| 21 days 4-5 leaf | 29 | 54 seminal roots only | 0.9 | 0.16 | 0.8 |
| 34 days 9-10 leaf | 400 | 4,400 | 19 | 2 | 19 |
| 49 days shoulder + | 3,300 | 15,700 | 116 | 12 | 143 |
| 71 days tassel | 9,500 | 32,200 | 199 | 28 | 231 |
| 79 days late silk | 11,200 | 38,100 | 218 | 29 | 222 |
| 93 days | 14,200 | 38,000 | 221 | 34 | 217 |
| 113 days | 19,800 | 20,700 | 262 | 39 | 269 |
| 132 days Black layer | 20,800 9,655 grain (204 bu/A) | 13,700 | 274 | 37 | 235 |

Mengel and Barber, 1974.

Between two and five weeks after pollination, kernel fill proceeded rapidly and the final nutrient uptake occurred. However, at this same time, the root system began to die back and root length was reduced almost 50% during this three week period. Leaf tissue also began to die back, at the lower part of the stalk, as the plant began to get rid of "excess baggage" as its job neared completion.

Over the last three weeks prior to black layer and maturity, the root system continued to decrease in size, and more leaf tissue died as the plant put the finishing touches on grain fill. Only about a 5% increase in dry weight was found during that last three weeks. No net increase in N or P was seen and K levels actually decreased as leaves died back and K began to leach from the stalk and leaves.

At maturity, 132 days after planting, over 20,000 pounds of dry matter had been produced with 46% being grain. Final yield was 204 bushels per acre.

This is just an example of how corn grows and develops. Root growth normally parallels stalk growth, and will usually reach a maximum some time around silking. However, a number of factors such as weather, compaction, fertilization practices, genetics, and pests can affect the size of the root system and the growth stage at which maximum root growth occurs.

An example of both genetic and management effects on root growth is shown in a recent study by MacKay and Barber (1986). They found that the time of maximum root growth differed between a short season hybrid, P3732, and the full season hybrid B73 x Mo17. P3732 reached maximum root elongation 75 days after planting, which corresponds to a few days after silking. B73 x Mo17 however, reached maximum root growth 91 days after planting, over two weeks after silking.

Table 2. Effect of Applied N on root growth, N uptake and yield of two corn hybrids.

| Hybrid and N Treatment | Days to maximum root growth | Root length per plant | N uptake | Grain Yield |
|---|---|---|---|---|
| | | meters/plant | lb N/A | bu/acre |
| B73 x Mo17 | | | | |
| 0 N | 91 | 880 | 103 | 79 |
| 200 N | 91 | 1425 | 177 | 114 |
| P3732 | | | | |
| 0 N | 75 | 750 | 103 | 79 |
| 200 N | 75 | 780 | 159 | 100 |

MacKay and Barber, 1986.

MacKay and Barber also varied N rates in their study. They found that when no N was applied both P3732 and B73 x Mo17 had similar maximum root lengths, around 800 meters/plant. In addition, both hybrids produced the same yield, 79 bu/acre, and took up the same amount of N from the soil, 103 pounds N/acre. At 200 pounds N/acre, both genotypes took up more N and produced higher yields, but only B73 x Mo17 showed increased root growth. Root length at 91 days increased from 880 meters/plant with no

N, to 1425 meters/plant with N.

This illustrates that corn hybrids can differ in how the below ground parts respond to management, just like they differ in yield potential and other characteristics.

Nutrient Uptake Patterns

In Table 3 are the rates of nutrient uptake in pounds per acre, per day, from our study of root growth. Nutrient uptake rates on a per acre basis increased rapidly and peaked during the rapid vegetative growth period from 34 to 49 days after planting. This would correspond to the time when corn grew from about 30 inches tall to head high.

Table 3. Nutrient uptake rates by corn at various stages during the growing season, expressed in pounds per acre, per day, and pounds per mile of root, per day.

| Growth Stage | Uptake N | Uptake P | Uptake K | Uptake N | Uptake P | Uptake K |
|---|---|---|---|---|---|---|
| | --- lb/A/Day -- | | | --lb/mile root/Day-- | | |
| Seeding to 21 days | 0.03 | 0.006 | 0.04 | $1.1x10^{-3}$ | $2.2x10^{-4}$ | $1.5x10^{-3}$ |
| (4-5 leaf) to 34 days | 1.4 | 0.1 | 1.4 | $6.3x10^{-4}$ | $4.5x10^{-5}$ | $6.3x10^{-4}$ |
| (9-10 leafs) to 49 days | 6.5 | 0.7 | 8.3 | $6.5x10^{-4}$ | $7.0x10^{-5}$ | $8.2x10^{-4}$ |
| (head high) to 71 days | 3.8 | 0.7 | 4.0 | $1.6x10^{-4}$ | $2.9x10^{-5}$ | $1.7x10^{-4}$ |
| (tassel) to 79 days | 2.4 | 0.2 | -1.1 | $6.8x10^{-5}$ | $5.6x10^{-6}$ | - |
| (late silk) to 93 days | 0.2 | 0.4 | -0.3 | $5.2x10^{-6}$ | $1.0x10^{-5}$ | - |
| (early milk) to 113 days | 3.1 | 0.1 | 3.8 | $1.1x110^{-4}$ | $3.4x10^{-6}$ | $1.3x10^{-8}$ |
| (dent) to 132 days (black layer) | -0.3 | -0.02 | -3.1 | - | - | - |

Mengel and Barber, 1974.

Also on Table 3 are the rates of nutrient uptake per mile of root. These values start out at very high levels and then drop off to 1/10 their initial rates at the same time nutrient uptake per acre is going up. The reason for this drop in uptake rate per root is the very rapid increase in root length occurring as the nodal root system takes over. Many of you can probably relate this to some of your own observations in the field.

Nutrient deficiencies are commonly seen on seedlings in the early spring, particularly in cool, wet years when root growth is limited. I'm sure many of you have seen plants grow out of nutrient deficiencies when the weather warms up in June. This is simply due to the tremendous demand placed on that tiny seminal root system about 2 to 3 weeks after planting. This also is the reason we see such large visual responses in early growth to starter fertilizer which may or may not follow through to increased yield. The high demand for nutrients per unit of root in these small plants makes them most susceptible to nutrient deficiencies, and most responsive to banded fertilizer.

Tillage effects on roots

Tillage and its associated effects on soil chemical and physical properties can have a tremendous effect on root growth. Some of these effects can be so large that they can, in turn affect yield. In Indiana, like Minnesota, we have a tremendous range in soil types. Some are well suited to no-till and give large yield increases when to reduced tillage is used. Some soils can support a wide range of tillage practices with little effect on yield one way or another. Others are not well suited to no-till and it is difficult to avoid yield reductions when no-till is applied. What I would like to do is look at three separate cases where a number of tillage systems were applied to a dark poorly drained prairie soil and discuss how root growth, nutrient uptake and yield were affected.

Case 1:

Don Griffith and Jerry Mannering at Purdue established a long term tillage study in 1974 to look at the suitability of a number of tillage systems for our prairie soils in Indiana. During 1980 and 1981 a graduate student, Jose Cruz, measured root growth, and a number of other variables on these plots.

Long term yield averages on this soil show that when corn is rotated with soybeans, normally very little difference in yield is found with different tillage systems. However, in some years differences do occur, and normally the no-till yields are lower than the others on these occasions.

The effects of three tillage systems on corn yield, when corn is rotated with soybeans, are presented in Table 4. In 1980, a very dry year, corn yields increased as tillage increased. During 1981, a very good, growing season, no measurable difference in yield was observed. These observations run counter to what many people would normally think. No-till should conserve moisture and prove beneficial in a dry year, but it wasn't.

The root distribution in this plot is presented in Table 5. Two things to note are the concentration of roots near the surface in no-till, and the differences between years in root density. In 1980, the dry year, root densities were higher in all tillage systems and at all depths than in 1981. The question is, was this increased root density a response to limited water, or was it a response to limits in nutrient availability?

Table 4. Effects of tillage system on corn yield at Lafayette, Indiana in 1980 and 1981.

| Tillage System | Corn Yield 1980 | 1981 |
|---|---|---|
| | --------bu/acre-------- | |
| Plow | 149 a | 169 |
| Chisel | 136 b | 171 |
| No-till | 135 b | 165 |
| | * | NS |

Cruz, 1982.

Table 5. Effect of tillage system on corn root distribution in a Chalmers silty clay loam soil.

| Depth | No-till 1980 | No-till 1981 | Chisel 1980 | Chisel 1981 | Plow 1980 | Plow 1981 |
|---|---|---|---|---|---|---|
| inches | ------------ | ------------ | ---mg root/cm$^3$--- | ------------ | ------------ | ------------ |
| 0 - 3 | 2.60 | 1.20 | 1.07 | 0.65 | 1.23 | 0.65 |
| 3 - 6 | 1.09 | 0.69 | 1.32 | 0.83 | 1.32 | 0.80 |
| 6 - 9 | 0.49 | 0.39 | 0.53 | 0.41 | 0.62 | 0.37 |
| 9 - 12 | 0.29 | 0.19 | 0.31 | 0.19 | 0.27 | 0.17 |
| 12 - 18 | 0.16 | 0.14 | 0.16 | 0.14 | 0.16 | 0.13 |
| 18 - 24 | 0.12 | 0.10 | 0.12 | 0.10 | 0.12 | 0.11 |

Cruz, 1982.

Table 6. Effect of tillage system on soil test levels at different depths in a Chalmers silty clay loam soil.

| Depth | No-till | | Chisel | | Plow | |
|---|---|---|---|---|---|---|
| | P | K | P | K | P | K |
| inches | ppm | | | | | |
| 0 - 3 | 80 | 250 | 77 | 209 | 35 | 130 |
| 3 - 6 | 25 | 105 | 33 | 109 | 42 | 151 |
| 6 - 9 | 16 | 88 | 14 | 88 | 26 | 130 |
| 9 - 12 | 10 | 96 | 10 | 96 | 10 | 96 |

Cruz, 1982.

Soil test results are summarized in Table 6. As you would expect, P and K were more uniformly distributed through the top 9 inches of soil where the soil had been plowed. Large accumulations of P and K were found in the top 3 inches of soil where the soil was chiseled and with no-till. Note also that below 3 inches, the fertility levels are fairly good, but not exceptionally high. In Indiana we would consider these levels below 3 inches in chisel and no-till adequate. Recommended rates of both P and K at the soil test levels found below three inches in no-till would be maintenance only.

Plant analysis data is given in Table 7. Again two interesting points should be emphasized. First a considerable difference in both P and K levels in the corn ear leaf are noted between 1980 and 1981. In 1980, the dry year with higher root densities, both P and K levels, were significantly lower than those found in 1981. Thus, nutrient utilization in 1980 was reduced. Secondly, notice that the K levels in 1980 were lower with chiseling and no-till than where the soil was plowed and the nutrients were more uniformly distributed through the top 9 inches of soil.

Table 7. Effect of tillage system on the nutrient content of corn leaves at silking.

| | Nutrient Content of Ear Leaf | | | | | |
|---|---|---|---|---|---|---|
| Tillage | N | | P | | K | |
| System | 1980 | 1981 | 1980 | 1981 | 1980 | 1981 |
| | % | | | | | |
| Plow | 2.82 | 2.79 | 0.24 | 0.31 | 177 a | 2.27 |
| Chisel | 2.73 | 2.89 | 0.23 | 0.32 | 156 b | 2.21 |
| No-till | 2.77 | 2.84 | 0.23 | 0.33 | 149 b | 2.27 |
| | NS | NS | NS | NS | ** | NS |

What conclusions can be drawn from this study? My interpretation is that under "normal" growing seasons, such as 1981, concentrating nutrients and roots near the soil surface in no-till or chisel fields will present no problems. However, in adverse years, such as 1980, nutrient uptake may be limited by moisture deficit and stratification can result in positional unavailability. If the lower portions of the soil have only modest soil tests, then nutrient deficiency can develop. Having higher soil test deeper in the soil, as was the case with plowing, minimized this problem.

Case 2:

A similar study to the one described in Case 1 above was conducted by Gyles Randall at the Southern Experiment Station from 1974 through 1977. Soil test levels at this site were similar to those at the Griffith-Mannering site.

Yield and K levels in the ear leaf are given in Table 8. Plowing gave highest yields with chiseling intermediate and no-till lowest. Leaf K levels followed a similar travel. Considering the drier climate at Waseca as compared to Lafayette, it may be that stratification of nutrients and roots resulted in limited K uptake.

Table 8. Effect of tillage method on corn yield, and leaf K content. Waseca, Minnesota.

| Tillage System | Ear Leaf K 1977 | Corn Yield 1977 | Corn Yield 1974-77 |
|---|---|---|---|
| | % K | ------bu/acre------ | |
| Fall plow | 1.99 | 159 | 135 |
| Fall chisel | 1.63 | 155 | 130 |
| No-till | 1.38 | 138 | 113 |
| $BLSD_{.05}$ | 0.19 | 10 | 10 |

Randall, 1978.

Case 3:

A more recent study, also conducted at Purdue, adds another dimension to the situation. This study was conducted on a very high fertility site with very high K levels throughout the top 12 inches of soil (Table 9). Corn and soybean yields from this site are given in Table 10. In 1982 an ideal year, no difference in yields of corn or soybeans are noted between the tillage systems used. However, in 1983, a record drought year, with temperatures over 100°F during corn pollination, yields were lower in no-till for both corn and soybeans. The question is, was it due to fertility and nutrient relations, or was some other factor involved?

Table 9. Effect of tillage on coil test levels at Falfayette, Indiana in 1984.

| Soil Depth | No-till P | No-till K | Chisel P | Chisel K | Plow P | Plow K |
|---|---|---|---|---|---|---|
| inches | ppm | | | | | |
| 0 - 4 | 49 | 270 | 43 | 242 | 30 | 191 |
| 4 - 8 | 35 | 197 | 31 | 178 | 28 | 188 |
| 8 - 12 | 19 | 185 | 13 | 162 | 22 | 189 |

Mengel, unpublished data

Table 10. Effect of tillage on corn and soybeans at Lafayette, Indiana in 1982 and 1983.

| Tillage | 1982 Yields Corn | 1982 Yields Soybeans | 1983 Yields Corn | 1983 Yields Soybeans |
|---|---|---|---|---|
| | bu/acre | | | |
| Plow | 205 | 65 | 171 | 66 a |
| Chisel | 206 | 64 | 171 | 63 a |
| No-till | 207 | 65 | 158 | 55 b |
| | NS | NS | NS | * |

Mengel, unpublished data

Root distributions with depth in all three tillage systems for both corn and soybeans are summarized in Tables 11 and 12. In the plowed plots, little difference in root distribution between years is noted for either corn or soybeans. However, a large difference, with the 1983 values sharply reduced, is noted in the chisel plowed plots of corn and soybeans. A similar decrease in root density is noted in the top 3 to 6 inches in no-till but root stratification is not as noticeable with the higher soil test levels depth.

Table 11. Effect of tillage on corn root distribution at Lafayette, Indiana in 1982 and 1983.

| Soil | No-till | | Chisel | | Plow | |
|---|---|---|---|---|---|---|
| Depth | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 |
| inches | mg/cm$^3$ | | | | | |
| 0 - 3 | 0.47 | 0.12 | 0.44 | 0.19 | 0.28 | 0.24 |
| 3 - 6 | 0.41 | 0.41 | 0.64 | 0.29 | 0.34 | 0.42 |
| 6 - 9 | 0.29 | 0.30 | 0.40 | 0.18 | 0.24 | 0.32 |
| 9 - 12 | 0.15 | 0.18 | 0.17 | 0.22 | 0.15 | 0.11 |
| 12 - 18 | 0.07 | 0.09 | 0.09 | 0.11 | 0.14 | 0.10 |
| 18 - 24 | 0.07 | 0.11 | 0.07 | 0.11 | 0.13 | 0.08 |
| 24 - 30 | 0.11 | 0.10 | 0.07 | 0.15 | 0.08 | 0.15 |

Mengel, unpublished data

Table 12. Effect of tillage on soybean root distribution at Lafayette, Indiana, in 1982 and 1983.

| Soil | No-till | | Chisel | | Plow | |
|---|---|---|---|---|---|---|
| Depth | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 |
| inches | mg/cm$^3$ | | | | | |
| 0 - 3 | 0.65 | 0.17 | 0.26 | 0.06 | 0.20 | 0.22 |
| 3 - 6 | 0.48 | 0.31 | 0.57 | 0.15 | 0.41 | 0.34 |
| 6 - 9 | 0.15 | 0.21 | 0.09 | 0.14 | 0.10 | 0.20 |
| 9 - 12 | 0.08 | 0.16 | 0.06 | 0.13 | 0.09 | 0.14 |
| 12 - 18 | 0.06 | 0.15 | 0.07 | 0.07 | 0.10 | 0.08 |
| 18 - 24 | 0.07 | 0.13 | 0.08 | 0.07 | 0.12 | 0.09 |
| 24 - 30 | 0.03 | 0.10 | 0.03 | 0.07 | 0.07 | 0.07 |

Mengel, unpublished data

The difference in root density did not result in lower nutrient uptake as measured by leaf analysis (Table 13). Values between years were similar, for both P and K. This would lead one to believe that when higher fertility levels are more uniformly distributed throughout the old plow layer, weather impacts on reduced yield would be reduced.

Table 13. Effect of tillage on P and K content of corn and soybean leaves at Lafayette, Indiana, in 1982 and 1983.

| Tillage | Corn | | | | Soybeans | | | |
|---|---|---|---|---|---|---|---|---|
| | 1982 | | 1983 | | 1982 | | 1983 | |
| Treatment | P | K | P | K | P | K | P | K |
| | % | | | | | | | |
| Plow | 0.27 | 1.96 | 0.24 | 2.25 | 0.35 | 2.16 | 0.33 a | 2.14 |
| Chisel | 0.28 | 2.07 | 0.24 | 2.19 | 0.32 | 2.07 | 0.31 ab | 2.11 |
| No-till | 0.26 | 2.03 | 0.23 | 2.20 | 0.34 | 2.23 | 0.30 b | 2.10 |
| | NS | NS | NS | NS | NS | NS | * | NS |

Mengel, unpublished data

## SUMMARY

In summary, there are two or three points which I would like to leave with you. First, we don't know as much about roots as we should. We are beginning to develop a general understanding of the growth and development of root systems. We are also beginning to discover how some of our management practices influence root growth and nutrient uptake. But this is an area of research which is in its infantcy and has a long way to go.

Second, changing tillage practices have a large effect on how roots and nutrients are distributed in soil. While this may not have any adverse effect on crop growth, nutrient uptake and yield can be influenced by the interaction of weather and fertility levels.

As we look down the road at research we may be able to use in the future, the work of Stan Barber on modeling nutrient uptake and root growth should prove extremely valuable. Hopefully, as we develop a better understanding of the interactions of soils and management practices on root growth, we will be able to apply his mechanistic approach to prescribe appropriate fertilizer placement methods and fertilizer rates to optimize nutrient uptake and yield. By placing fertilizer in the same places that the roots grow, we may be able to improve our efficiency and profits.

"PRODUCTION PLUS" WITH POTASSIUM

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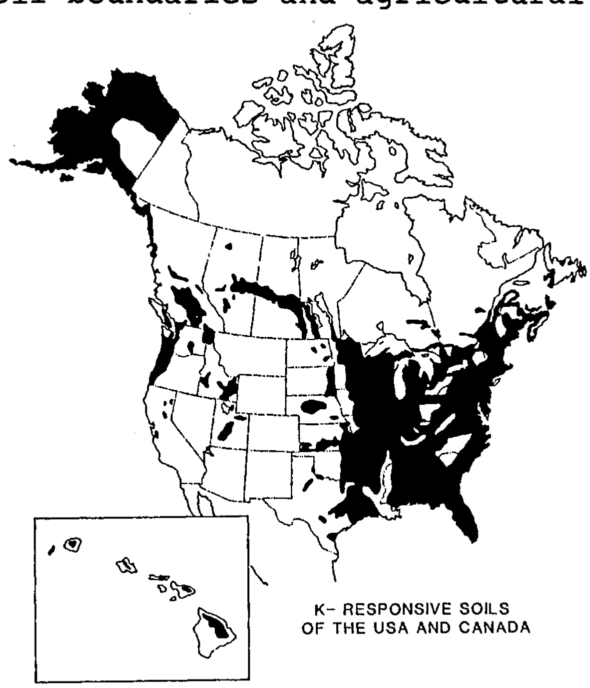
Potassium (K) is a nutrient which functions in many aspects of plant growth and development. We know that K is directly involved in the activity of at least 60 different enzymes. Most of these enzymes control reactions which capture and store energy from light and which release this energy from the storage products. Potassium is the most important regulator of cell turgor potential, thereby affecting growth, photosynthesis, respiration, and water use efficiency.

Most crops typically utilize about equal amounts of K and nitrogen (N) during growth, and because these are the two most prevalent mineral nutrients in most plants, it is not surprising that K fertilization is an important input of farming systems in many areas of the USA. Essentially the entire agricultural area east of the Missouri River contains soils that are responsive to K fertilization, except for the rich clayey soils of river flood plains and glacial lake beds (Figure 1). West of

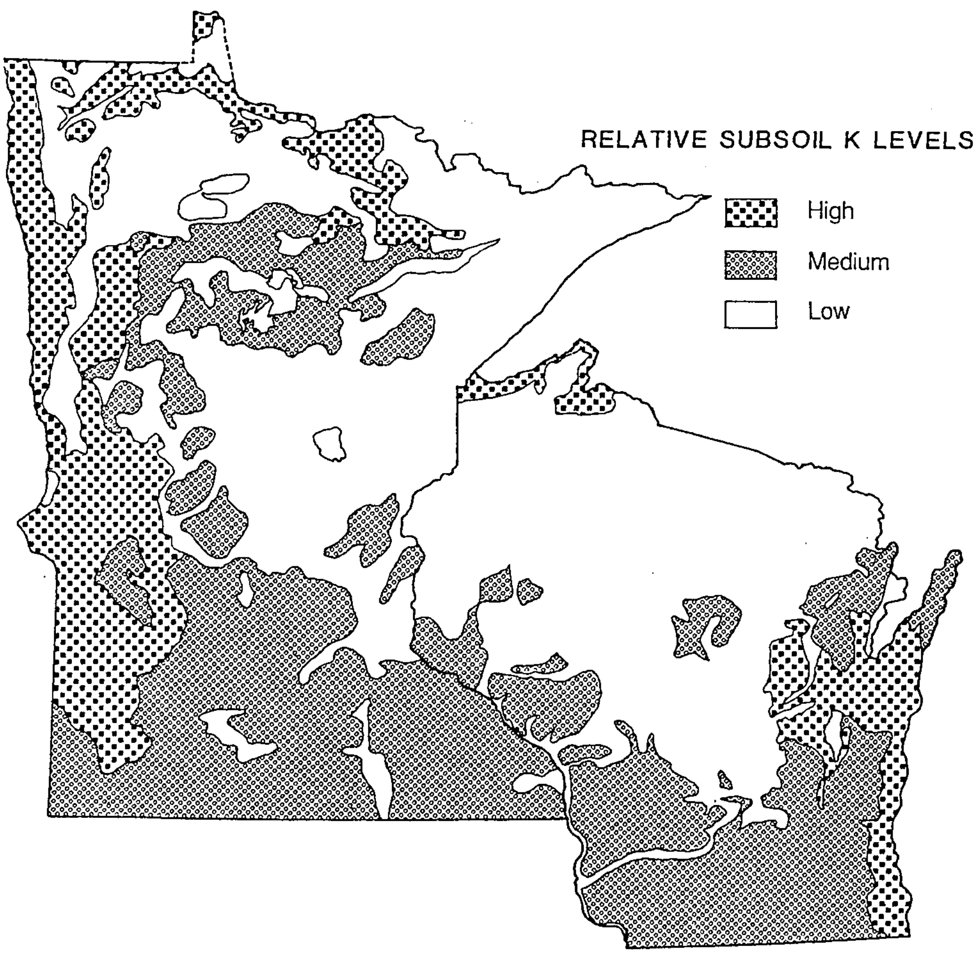
Figure 1. Generalized areas of soils in the USA and Canada on which crops frequently respond to K applications (based on responses to a survey of public soil testing laboratories in 1985 and on published reports; drawn to correspond generally with major soil boundaries and agricultural areas).



the Missouri river, crop yields on irrigated coarse-textured soils in arid regions and on the highly-weathered soils near the wet Pacific coast also benefit from K applications.

The need for fertilizer K is usually based on a test of the topsoil, but there are also large differences in subsoil K fertility, as well (Figure 2). These patterns arise because of differences in parent material from which soils develop and the formation and weathering (aging) processes which have occurred, and are presently occurring. In general, sandy soils are low in available native K and clayey soils are high in K. Low K supply by sandy soils is due to the lack of non-exchangeable K sources which can replace available K absorbed by the crop, and to the inability of the soil to retain unabsorbed fertilizer K against leaching, especially under irrigated conditions. However, absorption of K from subsoils and topsoils varies with crop species, management, and weather conditions.

Figure 2. Subsoil K status of soils in Minnesota and Wisconsin (Kelling et al., 1981; Rehm et al., 1985).



A comparison of the root length densities of alfalfa, orchardgrass, and corn can give an idea of the ability of these crops to compete for and acquire topsoil K and the ability to explore the subsoil for K (Table 1).

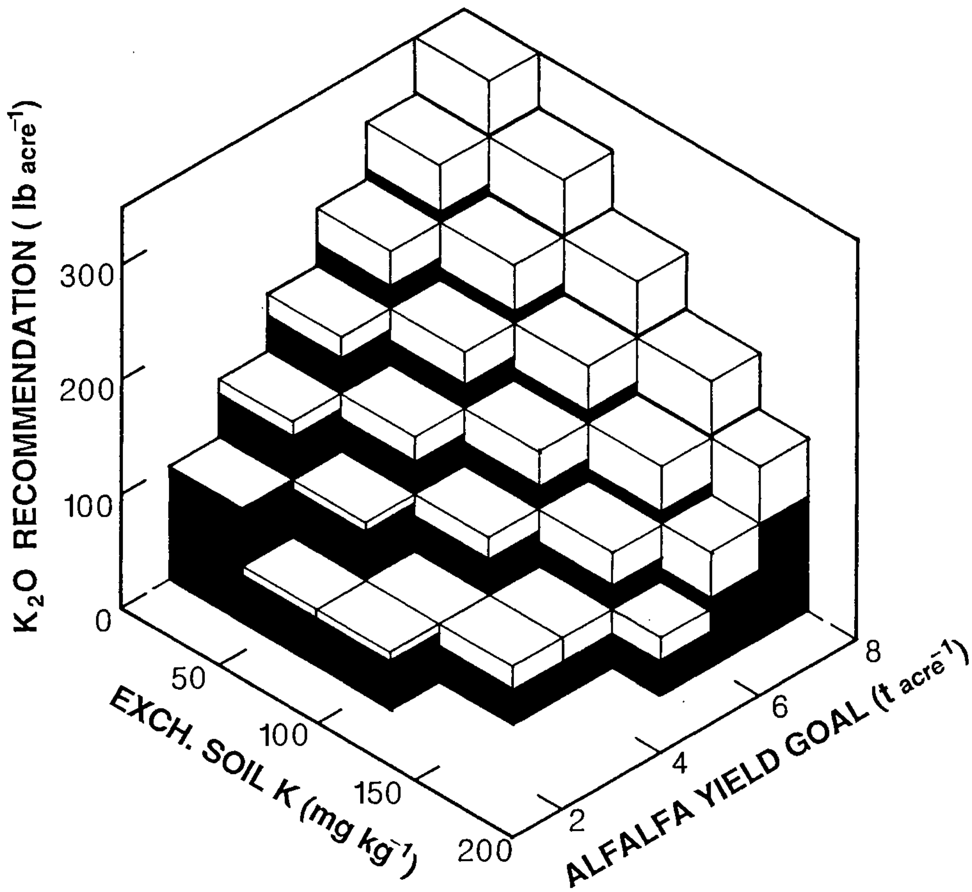
Table 1. Distribution of alfalfa, orchardgrass, and corn roots with depth during the summer (Evans, 1978).

| Depth | Alfalfa | Orchardgrass | Corn |
|---|---|---|---|
| inches | - - - - - - ft root/lb dry soil - - - - - - | | |
| 0- 8 | 55.9 | 239.2 | 64.6 |
| 8-16 | 10.6 | 35.7 | 7.7 |
| 16-24 | 6.7 | 14.9 | 5.8 |
| 24-32 | 4.6 | 8.3 | 3.3 |
| 32-40 | 3.1 | 6.3 | 1.9 |
| 40-48 | 3.1 | 4.0 | 1.3 |
| 48-56 | 2.1 | 3.9 | 1.6 |
| 56-64 | 2.5 | 0 | 0 |
| 64-72 | 2.1 | 0 | 0 |
| 72-80 | 1.8 | 0 | 0 |
| 80-88 | 1.2 | 0 | 0 |
| 88-96 | 1.6 | 0 | 0 |

Obviously, fertilizer K management must be adjusted for each crop, or in the case of pastures, for each crop combination. For example, in an alfalfa-orchardgrass pasture, the grass could certainly absorb more of the available K in the topsoil than the legume. Grasses typically can utilize more K from non-exchangeable soil reserves than legumes (Mengel and Kirkby, 1980). In a mixed pasture, K fertilizer rates need to be increased to provide sufficient K to the legume, especially if subsoil K reserves are low or if roots cannot penetrate the subsoil.

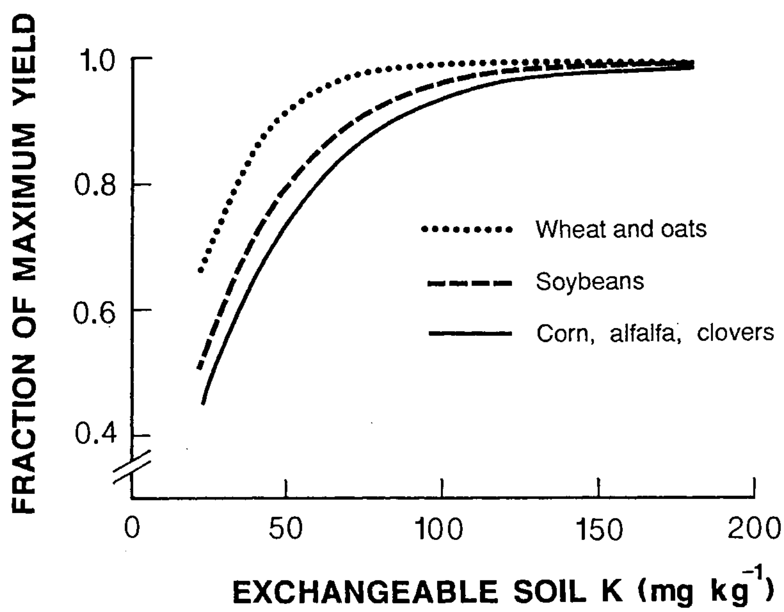
Potassium fertilizer requirements are also related to the yield potential of the crop. An example of K recommendations for alfalfa from the Soil Science Department of the University of Minnesota is shown in Figure 3. At a given soil test level, the rate of K fertilizer required to attain a desired forage yield increases with that yield goal, because the physiological requirement for K is relatively constant per unit yield. For a given yield goal, fertilizer requirements decrease with increasing soil test K values, because of the soil's increasing ability to supply K to the crop.

Figure 3. Fertilizer K recommendations for alfalfa in Minnesota for different soil test K levels (in ppm) and yield goals (Rehm et al., 1985). Dark columns are recommendations for fine- and medium-textured soils; light columns indicate the additional fertilizer required for coarse-textured soils.




Within a limited group of soils and growing conditions, we can predict the level of soil test K at which crop yields will be maximized. These groups will include soils of similar subsoil K supplying power, soil texture, cation exchange capacity (CEC), and organic matter content. For a group of soils in Illinois with CEC less than 12 meq/100 g, Bray found that near-maximum small grain yields could be attained with about 70 ppm exchangeable K, whereas corn and alfalfa required soil test levels of about 130 ppm (Figure 4). Somewhat higher soil test levels are required in Minnesota, because of cooler soil temperatures and shorter growing seasons.

Figure 4. Relationship between exchangeable K in topsoil (in ppm) and relative yield of several crops grown on soils of medium cation exchange capacity (Bray, 1945).




Potassium plays an important role in photosynthesis. Leaf initiation and development are improved with K additions, as is the rate of carbon dioxide fixation per unit leaf area (Cooper et al., 1967). Potassium fertilization also prolongs net carbon dioxide exchange in aging leaves and evidently favors the synthesis of the primary enzyme in photosynthesis, ribulose bisphosphate carboxylase (Wolf et al., 1976; Peoples and Koch, 1979). Because K is usually present in concentrations that should not limit enzyme activity, Mengel and Kirkby (1980) argued that improved photosynthesis is due to the positive effect of K on ATP synthesis, the compound which drives many of the enzymatic processes in cells.

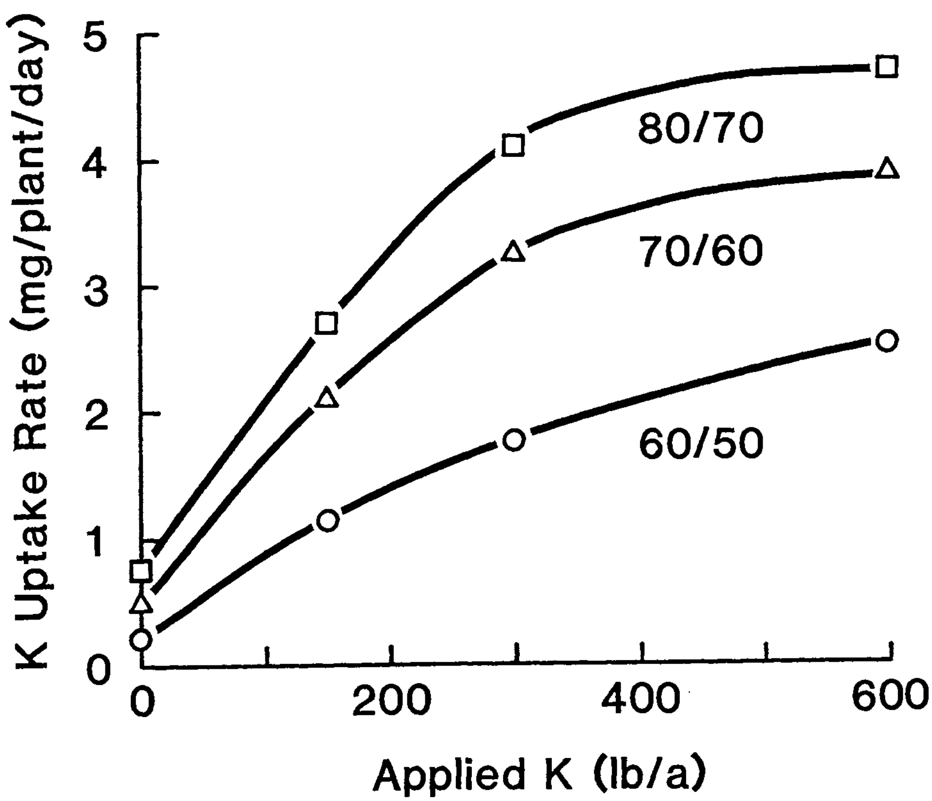
The utilization of photosynthate is also improved by better K nutrition. Barta (1982) found that effects of K nutrition on nitrogen fixation and growth of alfalfa were most pronounced during early regrowth, and that nitrogen fixation was no longer affected as the plants reached the bud stage of growth. He found no effect on nodule dry weight of total nonstructural carbohydrate content. Barta suggested that greater photosynthate transport to the nodules and improved use of these compounds in production of amino acids were the main factors which increased nitrogen fixation rates in alfalfa supplied with sufficient K. Brian Lang, a Ph.D. student in Agronomy and Plant Genetics, has initiated two experiments at Rosemount designed to determine whether K application, cultivar selection, and harvest management affect nitrogen fixation of alfalfa during fall and early spring regrowth.

With annual crops, the main emphasis in K fertilizer recommendations is generally placed on yield. However, with perennial crops, like forages, one must also consider stand persistence -- the ability to tolerate or resist diseases and to overwinter.

Several researchers have emphasized the importance of K in alfalfa winterhardiness. A few reports state that to attain optimum winter survival of alfalfa, higher K rates are required than for maximum yield of the crop. This is an intriguing observation, because it is difficult to conceive of a greater physiological need for K during dormancy than during active growth.

It is easy to imagine that a K-deficient plant will not be as able to withstand the rigors of winter as would a K-fertilized plant. Cooler soil temperatures in the fall may reduce K uptake rates (Smith, 1971; Figure 5). In his experiment, K concentrations at first flower under the coolest temperature

Figure 5. Temperature (day/night, $^{o}F$) effect on average K uptake rate during one alfalfa regrowth period (harvest to first flower) in pots containing low K soil (Smith, 1971).



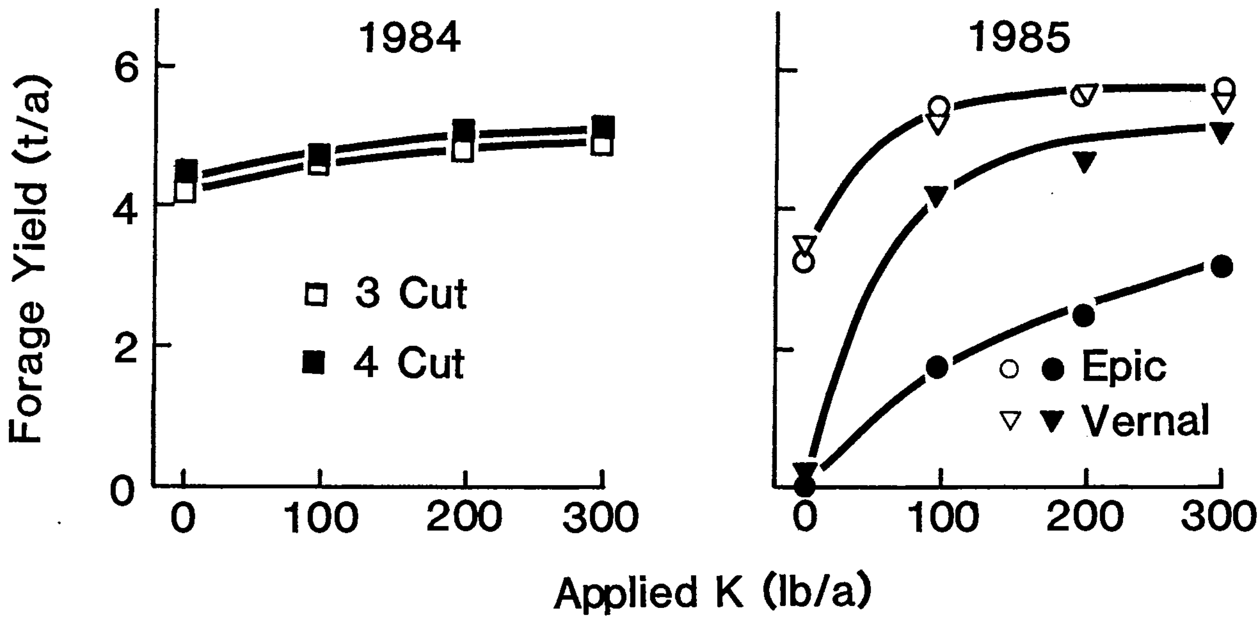
regime were less than 2% and all plants showed K deficiency symptoms. Part of this effect may be due in part to decreased water uptake rates at cool temperatures (Ehrler, 1963). Higher fertilizer rates, especially when applied during spring or early summer, would be needed to maintain adequate soil test K levels at lower soil temperatures. However, application of higher K rates early in the growing season may result in excessive absorption of K without an attendant yield increase ("luxury consumption"), thereby reducing the K use efficiency of the system. Soil texture and organic matter content will affect the conservation of K in the soil profile.

Dr. Craig Sheaffer and I conducted an experiment at Becker, MN, to test the interacting effects of K fertilizer management, harvest management, and cultivar on yield and persistence of alfalfa. The experiment was established on a loamy sand soil in spring, 1983. The experimental area was fertilized each year with sufficient S, Mg, and B to avoid deficiencies; soil P availability was high at this site. Plots were fertilized with 0, 100, 200, or 300 lb K/a as KCl. Vernal, a winterhardy, moderately high-yielding, traditional cultivar, and Epic, a moderately winterhardy, very high-yielding, new cultivar, were seeded at 15 lb/a within each K rate. All plots were irrigated and were harvested in mid-July and mid-August. Fall cutting managements consisted of: 1) no harvest after mid-August; 2) an additional harvest in mid-September; and, 3) an additional harvest in mid-October. Seeding year forage yields averaged 1.7, 2.1, and 2.3 t/a dry matter for Vernal and 1.9, 2.4, and 2.7 t/a for Epic under the three respective fall harvest systems. Epic was more responsive to K during fall growth than was Vernal and produced 0.62 and 0.85 t/a in mid-October with 0 and 300 lb K/a, respectively.

The winter of 1983-84 had very low air temperatures, but the ground was covered with sufficient snow to significantly reduce the depth and degree of soil freezing. There was no apparent stand loss during this winter. Potassium treatments were repeated, with one-half applied in early May and the other half after the second harvest. Plots were irrigated as necessary and were harvested at first flower in early June, mid-July, and mid-August, with fall harvest schedules as in 1983.

Total forage yields increased with applied K from 4.0 t/a for control plots to 4.9 t/a for the highest K rate (Figure 6). Potassium accumulation by the crop was over twice as great at the highest K rate as at the lowest (298 vs 116 lb K/a). Maximum yields were achieved with the 4-cut (Oct.) system, but the 3-cut system yielded only 0.27 t/a less dry forage. The 4-cut (Sept.) system had similar forage yield as the 3-cut system, primarily because lower yields early in the season were not offset by the additional 0.58 t/a obtained in the mid-September harvest.

Figure 6. Average forage dry matter yields of irrigated Epic and Vernal alfalfa at Becker, MN during the first production year (1984) under two cutting managements [3 cuts at first bloom before 15 Aug. (open symbols); 3 cuts before 15 Aug. plus a fourth harvest on 15 Oct. (closed symbols)], and forage yields following the stressful 1984-85 winter. One-half the K fertilizer was applied in early spring and the other half was applied after the second harvest.




During the 1984-85 winter, soil temperatures dropped to -4 $^{o}$F at 2 inches in the last week of December, because of insufficient snow cover. Stands in the most stressful fall harvest management system, the 4-cut (Sept.) system, were killed. Damage was also apparent in the lower K rate treatments of the 4-cut (Oct.) system.

This was the first growing season in which K deficiencies were observed in the nil K treatment. Vigor was reduced in all plots because of the winter damage and forage dry matter yields ranged from 2.4 to 5.6 t/a for Epic and Vernal fertilized with 0 and 300 lb K/a in the 3-cut system and from 0 to 3.2 t/a for Epic and 0.2 to 5.1 t/a for Vernal in the 4-cut (Oct.) system (Figure 6).

The most damaging effect to Vernal in the 4-cut (Oct.) system was seen in the first cut forage yields (Figure 7). Yield differences between the 4-cut Vernal and both cultivars in the 3-cut system were small in the second and third harvests. With proper management, even a marginally winterhardy cultivar like Epic can be maintained, but these cultivars will be damaged by combinations of intensive management and severe winters.

Figure 7. Forage dry matter yields of irrigated Epic (circles) and Vernal (triangles) alfalfa at each harvest of a 3-cut (solid line) and 4-cut (dotted line) system (see Figure 6 for explanation) following the stressful 1984-85 winter at Becker, MN.

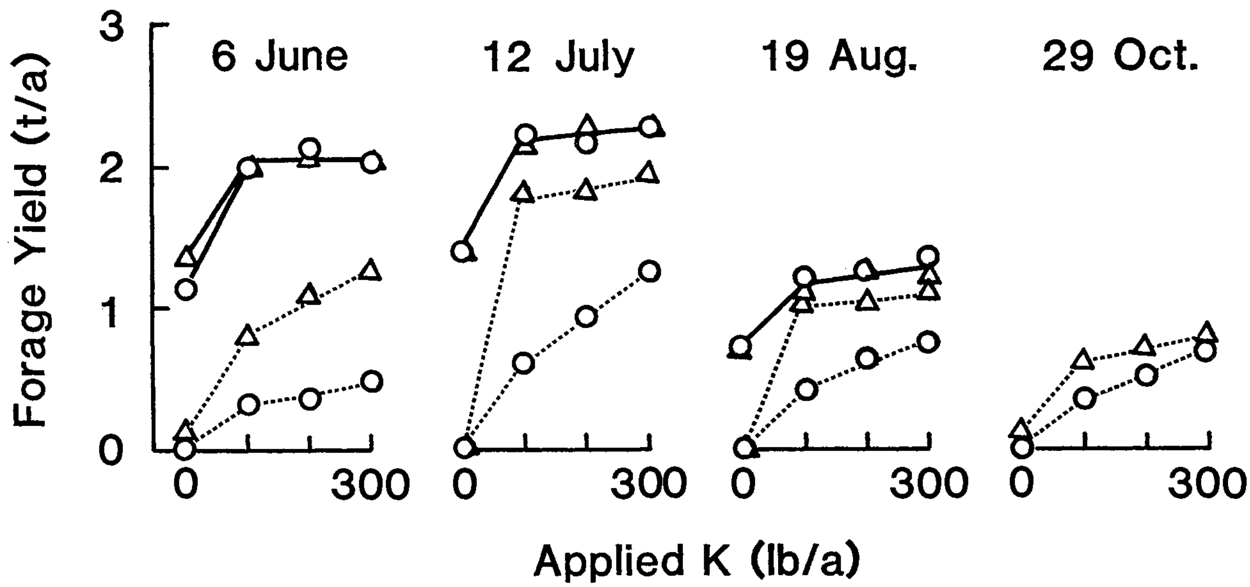
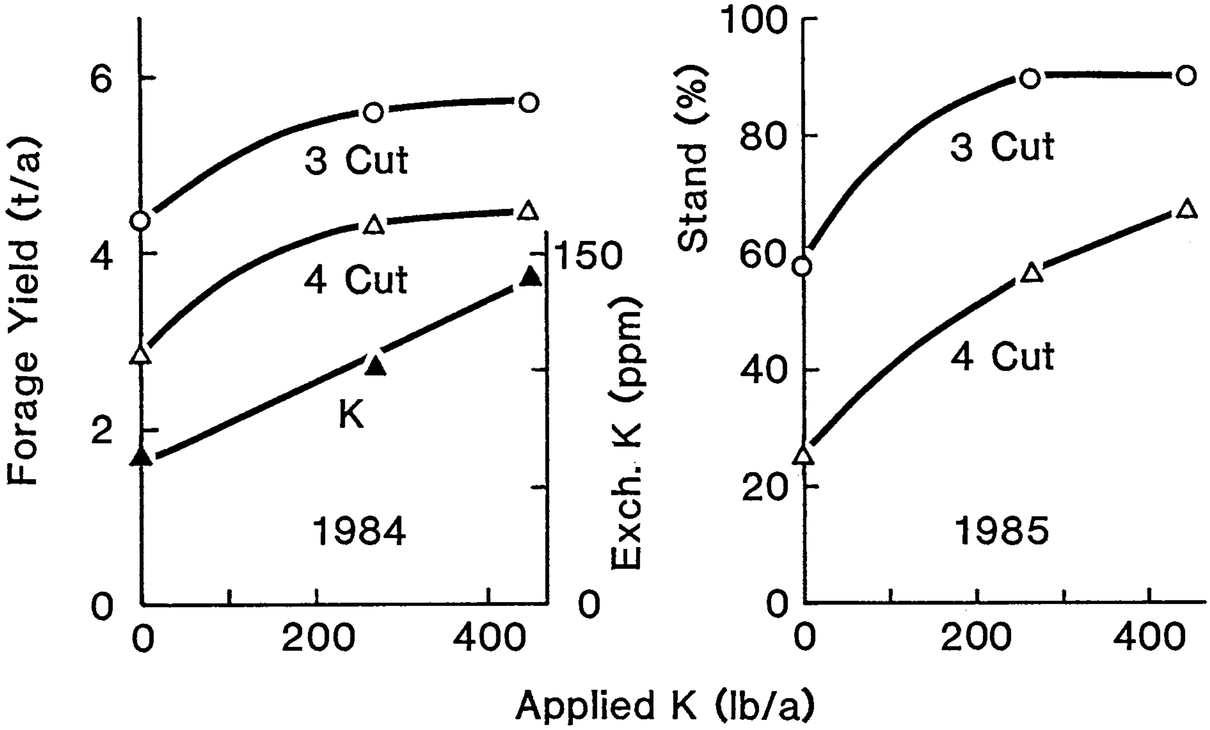



Figure 6 demonstrates the principle that K fertilization can help overcome the negative influence of intensive harvest management after a severe winter, if the cultivar is sufficiently robust. It also shows that higher K rates are required under intensive management than under lenient management. However, K applications of 300 lb/a did not reduce the damage to alfalfa harvested for the fourth time in mid-September, which would obviously be a risky management practice in Minnesota.

A second example comes from research conducted by Lang and associates at Arlington, WI. In the first production year on a silt loam soil, Blazer alfalfa yields for a 3-cut system (one-tenth bloom) and a 4-cut system (mid-bud) responded similarly to K additions. After the severe winter of 1983-84, yields the second production year were smaller in the 4-cut system, but each showed a maximum response at about 270 lb K/a (Figure 8). Soil test K levels in fall of 1984 increased linearly with added K, demonstrating the buildup of K achievable on fine- and medium-textured soils. The winter of 1984-85 was not as severe in southern Wisconsin as in Minnesota. Stands in spring in the 3-cut system were improved by the first increment of K only, and stands were much lower and continued to respond at higher K rates in the 4-cut system.

Figure 8. Total forage dry matter yields of Blazer alfalfa in 1984, exchangeable K in the topsoil in fall, 1984, and percent ground cover due to alfalfa in May, 1985, on a silt loam soil at Arlington, WI (B.J. Lang, unpublished data).




Potassium application can help reduce yield decreases due to moisture stress. Sheaffer and colleagues (1986) conducted an experiment on a sandy loam soil at Staples in which the treatments included irrigation rates, harvest management, and K fertilizer rates. Mean yields for unfertilized, irrigated alfalfa was 3.9 t/a, whereas nonirrigated alfalfa yielded 3.2 t/a when fertilized with about 450 lb K/a. Unirrigated, unfertilized alfalfa yielded only 2.4 t/a. It is remarkable that K application alleviated moisture stress to the extent observed, considering the limited soil moisture storage capacity of the this soil. After a severe winter, increasing K fertilizer additions reduced stand loss in irrigated alfalfa harvested at one-tenth bloom, and increased subsequent yield in all treatments.

We have been trying to determine what, if any, direct role K plays in alfalfa winterhardiness. Initially, we have focussed on the development of cold hardiness in the fall, because the length and characteristics of the regrowth period after a late summer harvest are crucial to the ultimate survival of the crop after a severe winter.

Epic alfalfa in the experiment at Becker was sampled every two weeks following the August harvest in 1985 until mid-November. Plants were divided into herbage, crowns, and roots, and dry matter accumulation, water content, pH, soluble protein, and freezing resistance were measured for each tissue. We also determined the ability of the plants to regrow in darkness, to measure the relative vigor and usable carbohydrates stored in the roots. We have found differences in many of these characteristics between plants showing visual K deficiency symptoms and those receiving K fertilizer. However, we found no differences among the K fertilizer rates of 100 to 300 lb/a, which we expected if high K rates promote hardening in fall.

Our research is continuing at an experiment at Rosemount. We planted Wrangler, Oneida, and Epic alfalfa in early summer, 1985, and have subjected them to two different harvest management systems (3 cuts at one-tenth flower and 4 cuts at mid-bud by early September, with no fall harvests). Plots have been fertilized with up to 415 lb K/a. Potassium deficiency symptoms were present the first fall on this silt loam soil. We have sampled the stands every two weeks during the fall, making several of the same determinations as in the Becker experiment and also measuring nitrogen fixation and disease incidence.

Potassium-deficient plants are often more susceptible to insect infestations and to diseases of both the shoots and roots (Eckstein et al., 1937). Recent reports draw conflicting conclusions about the efficacy of K in ameliorating specific diseases. Kelling and associates (1983) at Wisconsin found a trend for reduced Phytopthera root rot severity with increasing soil test K, but Alva and colleagues (1985) in Pennsylvania found neither decreased disease severity nor improved yield with K additions to a low K soil.

In our work with alfalfa, there appears to be an interaction between K nutrition and cultivar. Common leaf spot ratings were made in late August in the experiment at Rosemount. The ratings were made with 1 = no leaf spot present and 10 = severe leaf spot infestation accompanied by leaf loss. With no K applied to alfalfa since planting in spring 1985, Wrangler, Epic, and Oneida had ratings of 9, 7, and 5, repectively, whereas with annual applications of 415 lb K/a , leaf spot ratings were only 3, 2, and 2, respectively. At the high K fertilizer rate, little leaf spot was observed and there were no differences among these cultivars. The cultivars differed markedly when they were K-deficient. We have obtained root and crown samples from this experiment and will rate them for incidence and severity of diseases.

If K additions can decrease disease severity either through increasing resistance to attack by pathogens or through improving plant vigor and, therefore, tolerance to disease invasion, it is easy to imagine how persistence would be affected. Following those winters in which plants are stressed, but not killed, severely diseased plants will be less able to recover in spring. Plants stressed by frequent harvesting will be more susceptible to diseases. Thus, the improvement in the winterhardiness from K additions noted in our research and in that of others may be due in part to the effect of K on diseases.

Even if we find that high levels of available K are needed for optimum cold hardening during the fall, K may also affect some other aspects of alfalfa winterhardiness. Plants must not only be able to harden sufficiently in the fall, but they must be able to maintain dormancy through warmer periods, maintain vital life functions through the long winter by respiration of stored energy compounds, resist disease and insect invasions in spring, resist heaving during freeze-thaw cycles, tolerate poor aeration due to ice encasement, and effect rapid growth once spring arrives. If we can determine in which of these processes K plays a pivotal role under Minnesota conditions, we should be able to develop better fertilizer management schemes and should conceivably improve cultivar effectiveness in utilizing K for optimum winter survival. It is important that we develop better management systems to preserve stands of intensively-harvested, high-quality alfalfa.

## SUMMARY

As a major plant nutrient, K plays an integral role in photosynthesis, crop water potential, carbohydrate utilization, resistance to environmental and biological stresses, and in the ultimate expression of these factors -- yield. Crop requirements for K vary with the intensity of management, and an understanding of the interacting effects of soil, crop, and environmental characteristics is required to maximize K fertilizer use efficiency, crop yield, and persistence of perennial species.

## ACKNOWLEDGEMENT

The financial support by the Potash and Phosphate Institute of research conducted in cooperation with C.C. Sheaffer is greatly appreciated.

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# CORN AND SOYBEAN YIELD RESPONSE TO SOIL P AND K LEVELS

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Managing phosphorus (P) and potassium (K) in our soils can have a very direct effect on the profitability of crop production. Reducing production costs while maintaining yields and crop production potential are primary concerns of crop producers. Correct management can increase yields due to additions of fertilizer phosphorus and potassium and thus lower the cost of production per bushel or unit of yield, thus, enhancing profitability. Or correct management may reduce cost per bushel or unit of yield by reducing or eliminating applications of fertilizer phosphorus and potassium and, thus, reduce costs on fields that do not require additional P and K. An underlying question, however, is whether short term savings through reduced fertilizer use could result in long term losses.

Managing P and K requires that decisions be made on whether these nutrients are needed, and if they are needed how much to apply. Making these decisions requires current information on the available P and K levels of each field. This means soil testing.

A recent summary of soil test results from over 60,000 soil samples tested during the 1980-1985 period by the Iowa State University Soil Testing Laboratory shows that the average soil test value of these soil samples is high for both P and K but 30 percent of these samples show a need for fertilizer P and 40 percent show a need for fertilizer K. The question is, what kind of mix of needs does each field have for P and K? The answer can be gotten through soil testing.

## LOW TESTING SOILS

Large corn yield increases due to applications of fertilizer P on low to very low testing soils continue to be demonstrated. Table 1 shows data from a 29-year-old experiment conducted on a Webster soil. A 29-year average yield increase in excess of 35 bushels per acre has been obtained from fertilizer P applied only to corn in a corn-oat-alfalfa rotation. In this experiment, the 138-pound $P_2O_5$ rate is the only one that exceeds crop removal for the three crops and has had a small positive effect on soil test P. The plot receiving no fertilizer P has tested very low since the initiation of the experiment. A favorable year in 1985 caused a surprisingly high check yield of 144 bushels per acre, but yield was increased more than 35 bushels per acre due to fertilizer P. The efficiency of a small amount of fertilizer applied as a starter is evident from the average 18 bushels per acre increase where no broadcast P was applied over the 29-year period. Similar data for crop response to fertilizer K on low to very low testing soils are available.

## TRANSITION PERIOD

In the past 25 years the fertilizer industry has done an excellent job of transferring fertilizer P and K from the mines to midwestern fields. Even though crop yields and row crop acreage have increased, fertilizer P and K use

Table 1. Yields of corn as affected by rates of phosphorus and a starter fertilizer, Clarion-Webster Research Center, Kanawha.

| Broadcast[1] $P_2O_5$ | Starter[2] Fertilizer | Corn Yield 1985 | Corn Yield 1957-85 |
|---|---|---|---|
| lb/acre | | ------- bu/acre ------- | |
| 0 | No | 144 | 95 |
| | Yes | 143 | 113 |
| 46 | No | 169 | 126 |
| | Yes | 169 | 134 |
| 92 | No | 171 | 131 |
| | Yes | 169 | 135 |
| 138 | No | 181 | 131 |
| | Yes | 189 | 138 |

[1]Concentrated superphosphate is applied only to and plowed under for corn every three years in a corn-oat-meadow rotations.
[2]Starter fertilizer is 115 pounds per acre of 5-20-20.

has been nearly equal to or has exceeded crop removal of these nutrients (Table 2).

Table 2. Crop removal, fertilizer use and ratio of use to removal of P and K for selected years in Iowa.

| Year | Crop Removal[1] P | Crop Removal[1] K | Fertilizer Use[1] P | Fertilizer Use[1] K | Use/Removal P | Use/Removal K |
|---|---|---|---|---|---|---|
| | -------------- | tons | -------------- | | | |
| 1940 | 65,693 | 179,137 | 1,197 | 732 | 0.018 | 0.004 |
| 1945 | 64,571 | 177,784 | 10,226 | 6,239 | 0.158 | 0.035 |
| 1950 | 73,742 | 205,058 | 23,318 | 12,499 | 0.316 | 0.061 |
| 1955 | 78,903 | 223,406 | 44,001 | 41,325 | 0.558 | 0.185 |
| 1960 | 103,263 | 284,027 | 50,631 | 53,815 | 0.490 | 0.189 |
| 1965 | 112,845 | 308,422 | 99,207 | 115,700 | 0.879 | 0.375 |
| 1970 | 125,524 | 341,683 | 180,955 | 288,257 | 1.442 | 0.844 |
| 1975 | 153,009 | 397,154 | 186,785 | 367,546 | 1.221 | 0.925 |
| 1980 | 184,200 | 491,339 | 211,765 | 520,689 | 1.090 | 1.060 |
| 1984 | 179,816 | 444,455 | 174,516 | 502,984 | 0.971 | 1.132 |

[1]Removal and use are expressed in elemental P and K. Multiply P by 2.29 to obtain $P_2O_5$ and K by 1.2 to obtain $K_2O$.

The fertilizer use pattern is not evenly distributed across Iowa, and we would expect an increasing percentage of high testing fields and a decreasing percentage of low testing fields over time. Soil test summaries reflect fertilizer P and K use (Table 3). It is apparent that we now must become more concerned about appropriate profitable fertilizer use on high testing soils than on low testing soils.

Table 3. Percentage of soil samples analyzed by the Iowa State University Soil Testing Laboratory testing in various categories for P and K in different time periods.

| Soil Test Category | 1950's | 1964-1967 | 1968-1973 | 1974-1979 | 1980-1984 |
|---|---|---|---|---|---|
| | | | P | | |
| Very low to low | 67 | 60 | 52 | 39 | 31 |
| High to very high | 9 | 20 | 22 | 35 | 56 |
| | | | K | | |
| Very low to low | 26 | 16 | 22 | 18 | 15 |
| High to very high | 29 | 36 | 47 | 51 | 61 |

As soil test levels for P and K increased on many crop producers' fields in the 1970's, these producers started to ask some very penetrating questions. Some of these were: How high is high for a soil test value? Will a crop yield increase be obtained from a fertilizer P or K addition on a high testing soil? If a crop yield response to fertilizer P or K is not predicted on a high testing soil, how long can fertilizer P and K not be applied before the soil levels drop into the yield responsive range? And if a soil test level is to be maintained, how much fertilizer P or K must be applied each year or every other year? These questions are even more important now because of the economic situation of many crop producers.

## FIELD RESEARCH

Because there was not adequate research information to answer the preceding questions, field research was initiated in 1974 and 1975 to provide such information. The general approach was to create high and very high soil test levels for P and for K in separate experiments for each nutrient. This was done by applying high rates of fertilizer P or K to establish large blocks for each test level. Annual rates of P or K were started on each test level the following year. The selected annual rates were our estimate of 1/2X, 1X, and 1 1/2X annual average crop removal by a corn-soybean sequence. The experiments are soil sampled annually in late September or early October prior to crop harvest. After harvest the annual fertilizer P and K treatments are applied broadcast. Fall chiseling has been the primary tillage practice. Blanket applications of fertilizer P are made on the K experiments and K on the P experiments. Fertilizer N as broadcast urea is applied for corn and tilled in during land preparation for planting. These particular experiments were established at two locations in the Clarion-Webster soil association.

These soils have very low levels of available P and K in the subsoils. The results from the two experiments for each nutrient have paralleled each other. Because of this close agreement, only data from one experiment for P and one for K will be discussed.

P Results

Corn and soybean yields from the P experiment are shown in Table 4 for the 5th and 10th years, and average yields for the first and second five year periods are given.

Because the untreated soil at this experimental site initially tested in the medium range (35 lb) in P, crop response to the annual P additions was practically nil for the first two or three years of the study. As the soil test level dropped into lower ranges, responses gradually developed until yield increases of 4 to 8 bushels of soybeans and 30 to 40 bushels of corn were measured the last three or four years. Most of the yield response was obtained in the lowest testing block and the 46-pound $P_2O_5$ annual rate was sufficient for maximum yields in this block. On the intermediate testing basic block for the zero annual treatment, the soil test has dropped into the low category and yields have begun to drop accordingly. Annual treatments have not produced yield increases on plots still testing high or very high. (See Table 5 for interpretations of soil test values).

Soil test P levels have declined where annual treatments were omitted or were less than crop removal, but the rate of decline has not been as rapid as anticipated as shown in Figure 1. On the basic treatment initially testing medium, the P soil test has dropped from 35(M) to 15 pounds (VL) when annual treatments were not applied for the 10-year period. Annual applications of 46 pounds $P_2O_5$, which approximates average annual removal for this corn-soybean sequence, have nearly maintained P soil tests on all of the basic levels. Soil tests have declined with the 23-pound $P_2O_5$ annual rate and have increased slightly with the 69-pound $P_2O_5$ rate.

The effect of residual soil P (soil test levels) on corn and soybean yields can be visualized by expressing each year's yields as a percentage of the maximum yield obtained that year in the experiment and the plotting these percentages against the respective soil test value. These percentages are shown in Figure 2 for only those treatments that have received no additional fertilizer P since the initial P levels were created in 1975. The data are more consistent for corn than for soybeans, but both crops show little decline in yields until the low level is reached. There is a considerable effect in the low part of the low category compared to the high part of this category. Knowing the reported test value is more important than knowing just the soil test category. Soils that test in the high category should produce 95 to 100 percent of the potential yield without additional fertilizer P. Although figure 2 illustrates little risk in skipping fertilizer P on high testing soils, it does illustrate a 25 to 30 percent reduction in potential yield at the low to very low soil test P level if no fertilizer P is applied.

Figure 2 is a good illustration of the calibration of a soil test. These data aid in the interpretation of soil test values into the various categories. However, these data are not sufficient to specify what the economic optimum fertilizer P rate should be. Separate experiments on low and very low testing sites are used to provide a basis for determining fertilizer P recommendations.

Table 4. Corn and soybean yields and soil phosphorus tests for the residual P experiment established in 1975 at the Clarion-Webster Research Center, Kanawha (courtesy of Dr. John Webb).

| Annual $P_2O_5$ | Soil Test* P | | Corn Yields | | | | Soybean Yields | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| lb/acre | lbs/acre | | bu/acre | | | | | | | |
| | 1979 | 1984 | 1980 | 1976-80 | 1985 | 1981-85 | 1980 | 1976-80 | 1985 | 1981-85 |
| Initial Medium Level | | | | | | | | | | |
| 0 | 19(L) | 14(VL) | 158 | 146 | 145 | 137 | 39 | 39 | 25 | 34 |
| 23 | 29(M) | 23(L) | 167 | 151 | 175 | 163 | 42 | 40 | 31 | 40 |
| 46 | 33(M) | 37(M) | 165 | 151 | 186 | 171 | 44 | 41 | 31 | 39 |
| 69 | 49(H) | 64(VH) | 171 | 156 | 188 | 173 | 42 | 41 | 29 | 40 |
| Initial High Level | | | | | | | | | | |
| 0 | 53(H) | 26(L) | 170 | 157 | 175 | 168 | 44 | 41 | 29 | 39 |
| 23 | 65(VH) | 45(H) | 170 | 155 | 180 | 172 | 43 | 41 | 32 | 40 |
| 46 | 74(VH) | 71(VH) | 166 | 154 | 186 | 171 | 43 | 41 | 30 | 40 |
| 69 | 89(VH) | 91(VH) | 167 | 154 | 189 | 176 | 42 | 41 | 32 | 40 |
| Initial Very High Level | | | | | | | | | | |
| 0 | 86(VH) | 52(H) | 169 | 152 | 187 | 171 | 40 | 40 | 31 | 39 |
| 23 | 102(VH) | 76(VH) | 168 | 152 | 182 | 171 | 40 | 40 | 31 | 39 |
| 46 | 106(VH) | 99(VH) | 170 | 151 | 181 | 172 | 40 | 39 | 32 | 39 |
| 69 | 123(VH) | 117(VH) | 161 | 149 | 185 | 171 | 39 | 39 | 32 | 39 |

*VL = Very Low, L = Low, M = Medium, H = High, VH = Very High.

Table 5. Interpretations of soil test P and K values made by Iowa State University Soil Testing Laboratory.

| Soil Test Level | P | K |
|---|---|---|
| | ----------- lb/acre or pp2m | ----------- |
| Very Low | ≤15 | ≤70 |
| Low | 16-30 | 71-135 |
| Medium | 31-40 | 136-200 |
| High | 41-60 | 201-300 |
| Very High | >60 | >300 |

K Results

Corn and soybean yields from the K experiment are shown in Table 6. Although a corn-soybean sequence is grown, only corn and soybeans are grown every other year. The average yields from each crop within a 5-year period are for either 2 or 3 years as noted in Table 6.

Yield response to the annual K additions the first 5-year period was confined to the basic block initially testing low. In the second 5-year period the soil test level on the basic block initially testing medium dropped into the low category and yield responses were obtained to annual K additions. For the basic block initially testing high the soil test level for the treatment receiving no annual K has dropped into the low category and yield responses are now expected.

Yield responses of 30 to 40 bushels of corn and 8 to 10 bushels of soybeans are being obtained on the low initial level. The yield responses have been directly proportional to the soil test level. By using the percentage of maximum yield produced by residual soil K only, the effect of soil test level on corn and soybean yields is shown in Figure 3. The effect of soil test K level on yields is similar to that shown for P. There is very little effect of additional fertilizer K on corn or soybean yields at the high and very high soil test levels, but there is a rapid decline in yields in the low to very low soil test K categories. A decrease in yield of 20 to 25 percent from the potential yield can occur on the low to very low testing soils if no fertilizer K is applied. There appears to be little risk of yield reduction by skipping fertilizer K on the high testing soil.

Where no annual fertilizer K additions have been made since 1975, the decline in soil test K values has been greater than anticipated (Figure 4). Even though some of the annual additions have been equal to or have exceeded crop removal, soil test K levels have declined. As a consequence, the annual fertilizer K additions were increased as footnoted in Table 6. Based on other data, crop removal of K is not thought to be a major factor. Either the added K has changed to a form that is not extracted by the soil test, or the time of sampling in late September or early October, when much K is still in the crop plants, does not reflect what is available to next year's crop. It should also be noted that the soil test for K is run on field moist soils and the results are lower than those obtained on dried soil samples. It appears that

Table 6. Corn and soybean yields and soil potassium tests for the residual K experiment established in 1975 at the Clarion-Webster Research Center, Kanawha (courtesy of Dr. John Webb).

| Annual* $K_2O$ | Soil test** K | | Corn Yields | | | | Soybean Yields | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| lbs/acre | lbs/acre | | | | | | | | | |
| | 1979 | 1984 | 1980 | '76,78,80 Ave. | 1984 | '82,84 Ave. | 1979 | '77,79 Ave. | 1985 | '81,83,85 Ave. |
| | | | bu/acre | | | | | | | |
| Initial Low Level | | | | | | | | | | |
| 0 | 87(L) | 84(L) | 147 | 134 | 122 | 142 | 34 | 33 | 15 | 28 |
| 24 | 100(L) | 88(L) | 157 | 142 | 147 | 160 | 36 | 34 | 20 | 36 |
| 48 | 101(L) | 105(L) | 155 | 144 | 155 | 168 | 38 | 36 | 26 | 36 |
| 72 | 116(L) | 133(L) | 163 | 150 | 162 | 173 | 40 | 37 | 26 | 36 |
| Initial Medium Level | | | | | | | | | | |
| 0 | 112(L) | 93(L) | 157 | 149 | 147 | 164 | 38 | 37 | 16 | 32 |
| 24 | 123(L) | 103(L) | 162 | 149 | 156 | 169 | 40 | 37 | 19 | 34 |
| 48 | 129(L) | 127(L) | 162 | 150 | 160 | 171 | 39 | 37 | 22 | 35 |
| 72 | 150(M) | 139(L) | 164 | 149 | 158 | 171 | 40 | 38 | 31 | 39 |
| Initial High Level | | | | | | | | | | |
| 0 | 194(M) | 121(L) | 172 | 151 | 158 | 170 | 42 | 38 | 23 | 37 |
| 24 | 236(H) | 154(M) | 171 | 153 | 157 | 171 | 41 | 37 | 24 | 36 |
| 48 | 263(H) | 219(H) | 171 | 152 | 164 | 174 | 41 | 37 | 27 | 37 |
| 72 | 280(H) | 227(H) | 169 | 149 | 156 | 171 | 40 | 37 | 25 | 35 |

*Annual rates are now 0, 36, 72 and 108 lb $K_2O$ since 1982.

**L = Low, M = Medium, H = High.

when no fertilizer P and K are applied to high testing soils for several years, it is more important to have a regular soil testing program for K than for P so that available soil K doesn't decline to a yield limiting level.

## SUMMARY

1. Soil testing provides a basis for making decisions on the necessity of applying fertilizer phosphorus and potassium and the economic risk if none is applied.

2. Proper interpretation of soil test values provides an expectation of effect of soil P and K on potential yield.

3. Soil testing can aid in setting priorities for allocating limited funds for fertilizer P and K.

4. Management of soil P and K for profitability depends on knowledge of available P and K levels.

5. Because the percentage of soil samples testing high to very high is increasing (at least in Iowa), it is more important to use soil testing now to separate high testing from low testing fields than it was 20 years ago.

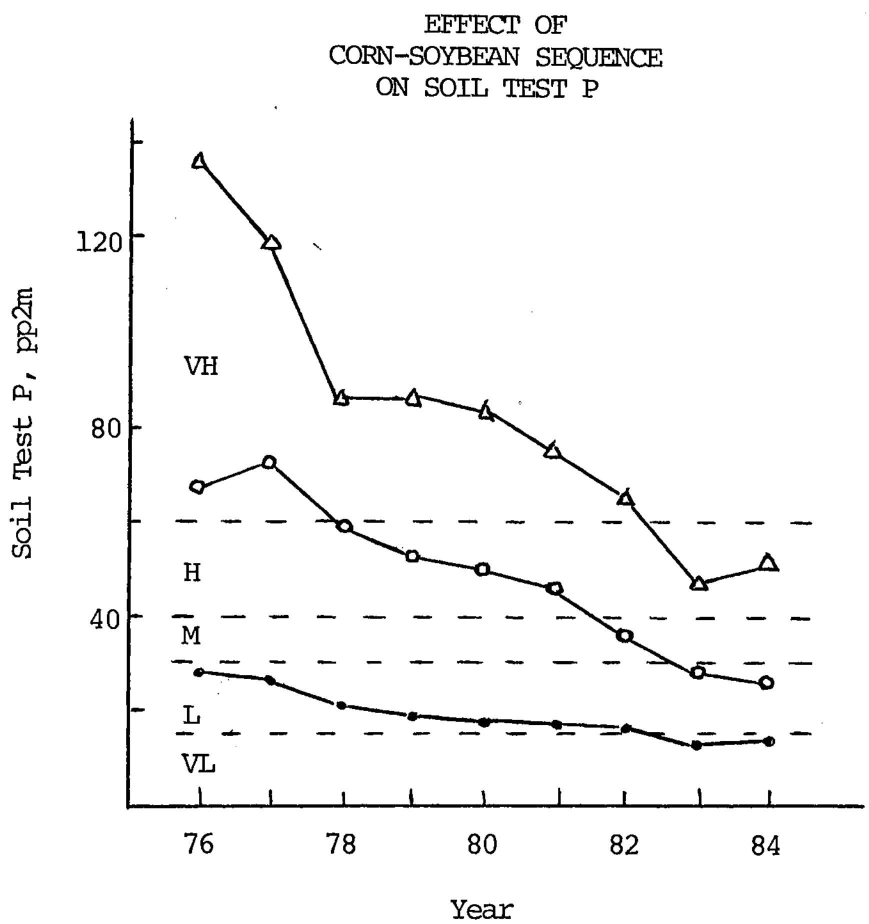
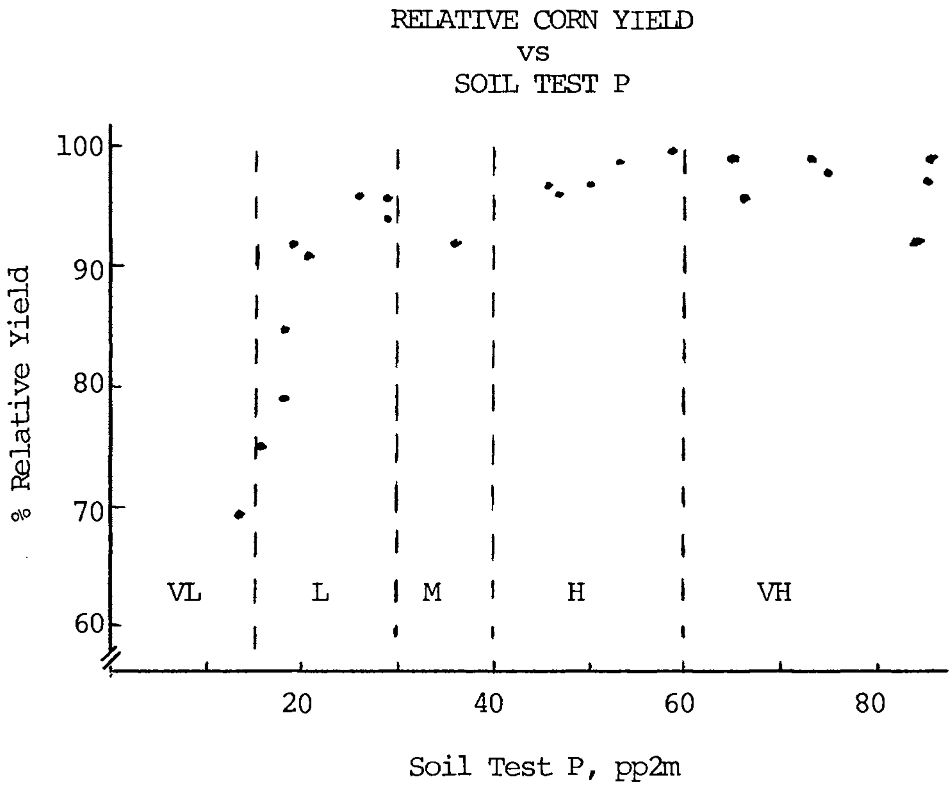



Fig. 1. Decline in soil test P for different initial soil P levels due to not applying fertilizer P to a corn-soybean sequence over a 9-year period.



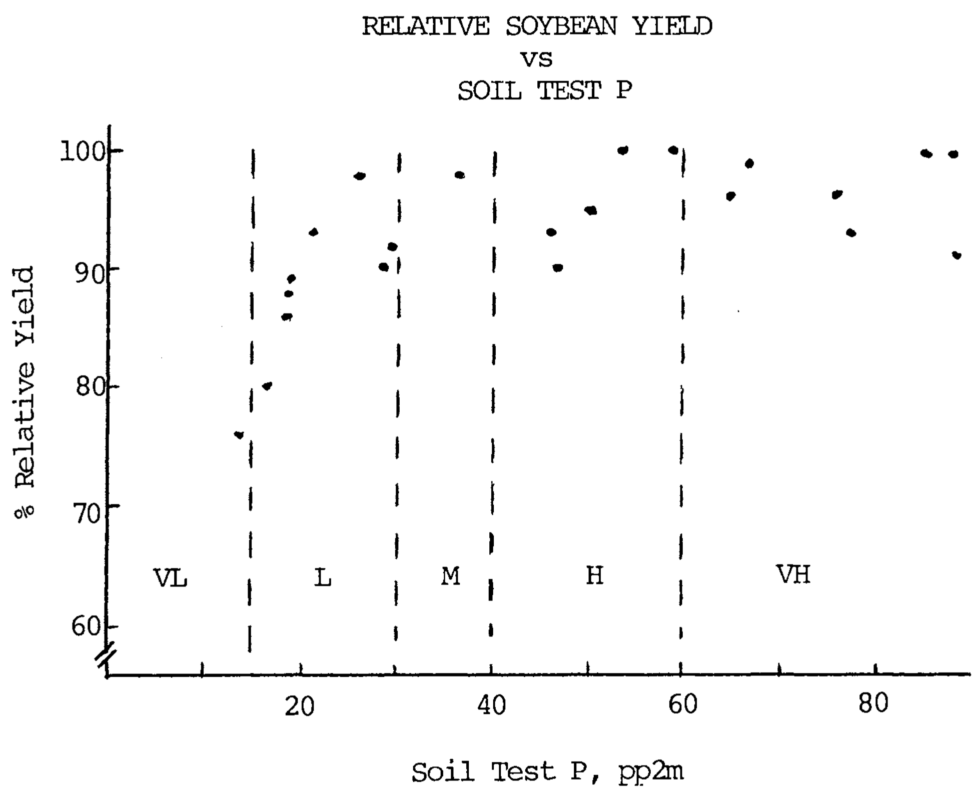
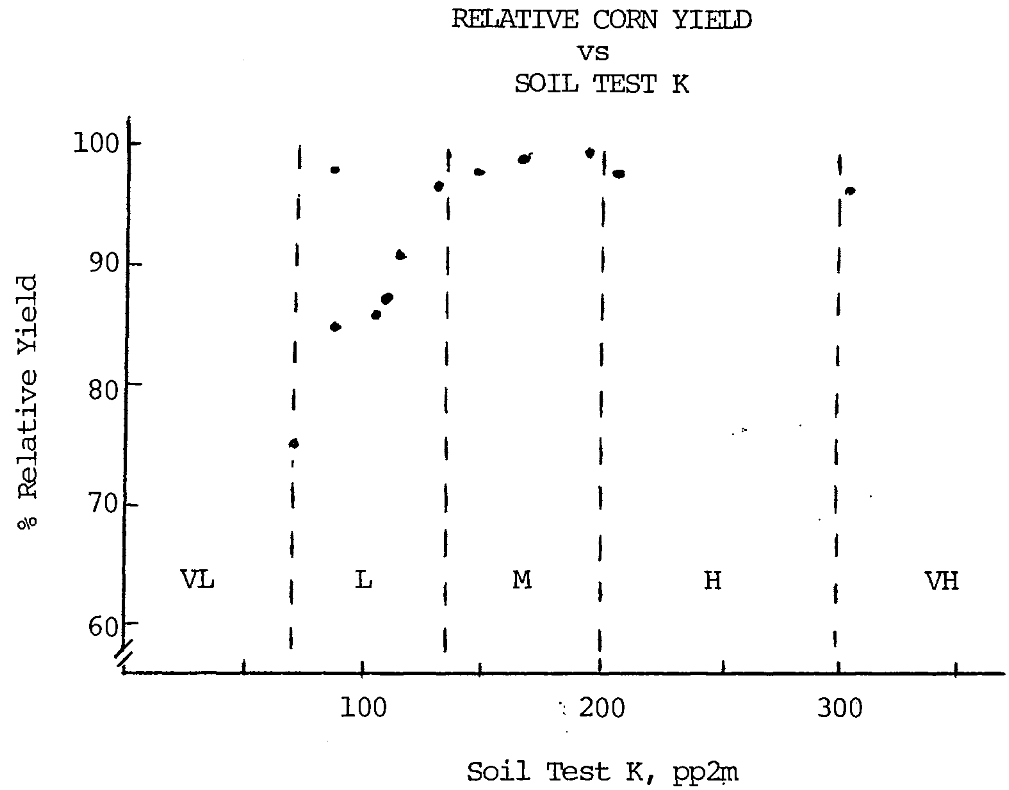




Fig. 2. Effect of P soil test level on percent relative corn and soybean yields over a 10-year period.



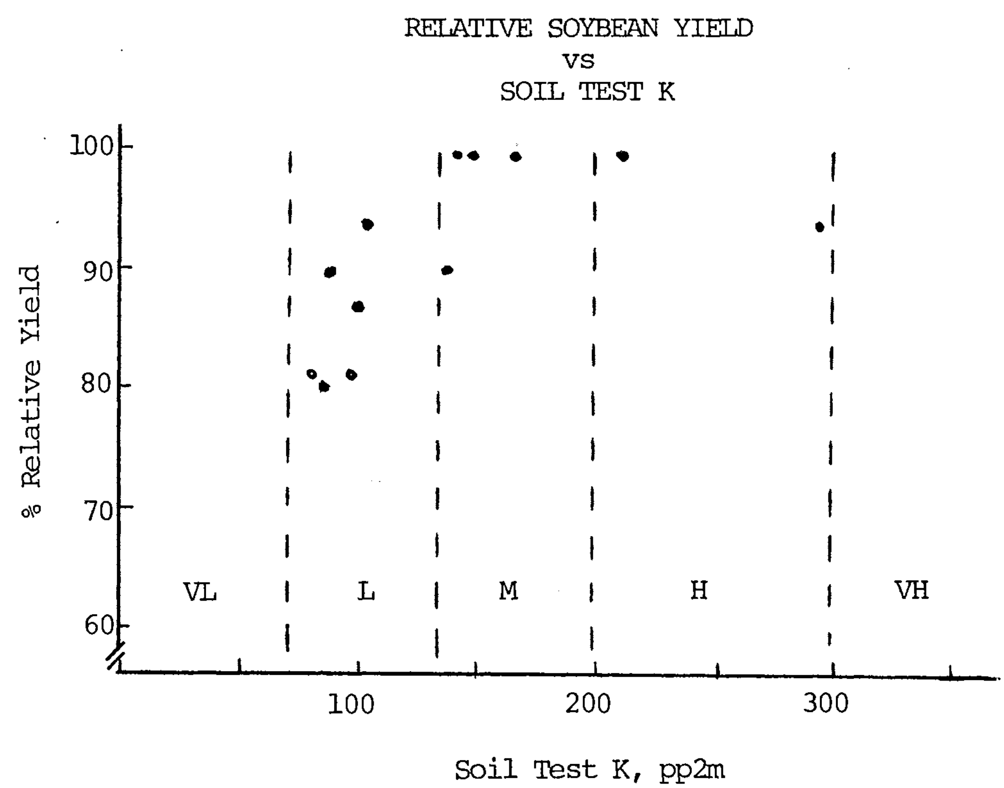




Fig. 3. Effect of K soil test level on percent relative corn and soybean yields over a 10-year period.

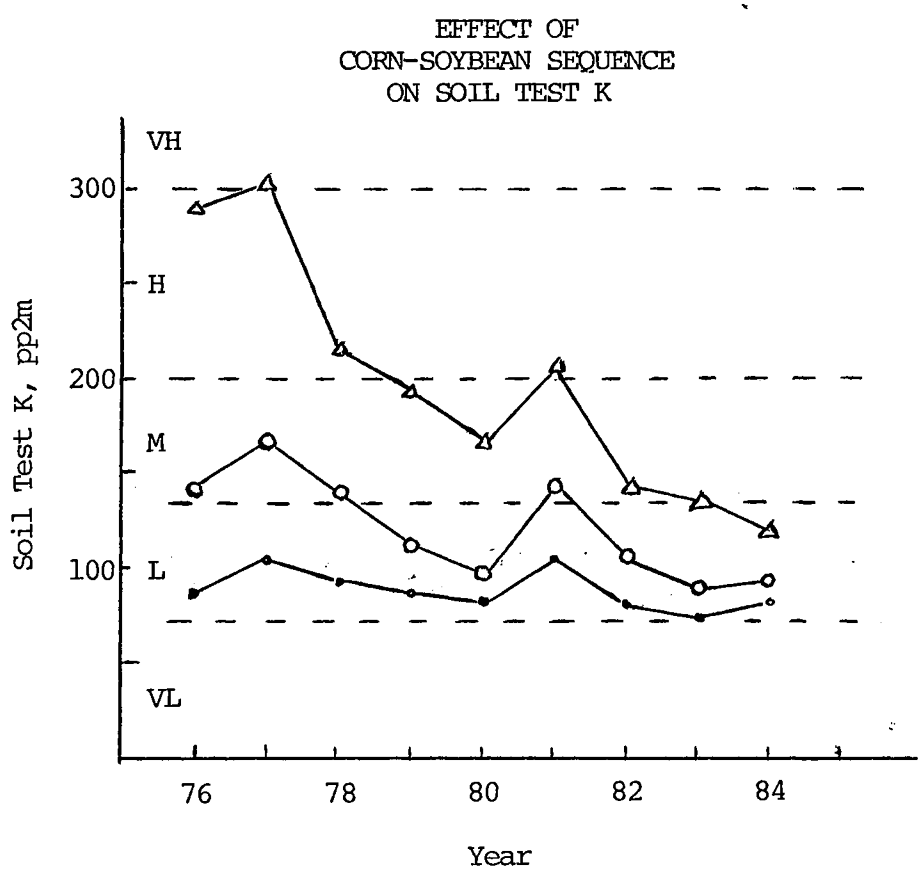



Fig. 4. Decline in soil test K for different initial soil K levels due to not applying fertilizer K to a corn-soybean sequence over a 9-year period.

# LIQUID UREA: PROBLEMS AND POSSIBILITIES

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The increased availability of low cost urea to the U. S. fertilizer dealer has caught the attention of the fluid segment of the industry. Some of the imported urea is not up to U. S. quality standards for particle size uniformity and it is difficult to use satisfactorily for direct application or dry blend formulation in dry solid form. Some fluid manufacturers have dissolved this material for use as a nitrogen solution and others are considering taking this step.

Dealers who are interested in dissolving solid urea for sale as a nitrogen solution should base their decision on two factors. One is a manufacturing factor and the other is the agronomic performance factor of the end product. The typical U. S. produced urea-ammonium nitrate (UAN) is the foundation nitrogen source for the fluid industry. It was developed by a U. S. nitrogen producer about 40 years ago and has been available to the market since that time as a 28%, 30% or 32% nitrogen product. The 28% and 32% formulations are primarily used in northern states.

Dealers should not overlook the fact that most producers of UAN nitrogen solution have basic supplies of anhydrous ammonia, urea, ammonium nitrate and other nitrogen products. It has always been within their capability to produce any of the urea solution products that can be made by dissolving solid urea. The fact that they have not done so indicates that these products lack some of the desirable characteristics of UAN solution.

Cost of end product will be the principal factor that most dealers will consider. If the typical UAN solution is cost competitive with fluid urea solution, there probably is no reason to dissolve solid urea. The cost of UAN solution is easily determined by obtaining price quotes from producer sales personnel. The cost of urea solution will vary from dealer to dealer. The price of urea is obviously a key factor. Beyond urea price, one must develop accurate cost figures for converting solid urea to a fluid in order to arrive at the true cost of urea solution.

The first processing cost must be charged to the handling of dry solid urea from delivering carrier into storage and from storage to the point where it will be dissolved. The cost will vary depending on whether existing equipment and facilities can be used or new construction is required. If new construction is required, the return on capital must be prorated over time and it will be necessary to project what the price relationship will be between urea and UAN over time.

The second processing cost will be charged to the dissolving step. When urea is added to water, there is a drop in temperature. To maintain sufficient temperature to dissolve urea with a reasonable degree of efficiency in the process, a supplemental heat source will be needed to produce a water temperature of 70° F or greater. The higher the temperature, the faster urea will dissolve. Some with experience in dissolving urea state that each 100 pounds of urea that goes into the mix will drop water temperature about 1° F. Anhydrous ammonia can be added to the mix to produce heat if proper safety procedures are followed. If anhydrous ammonia is not currently handled at the installation, insurance coverage should be checked before it is brought on site. Some thought must also be given to how well the requirements for dissolving urea will fit into the overall logistic pattern of the installation. In a busy spring season, labor, storage and materials handling equipment are already taxed to capacity at some installations.

The third processing cost is charged to the storage and handling of the end product. The characteristics of a urea solution are not the same as those of a UAN solution. A solution of urea containing 50% urea by weight contains 23% nitrogen by weight (23-0-0) and has a salting-out temperature of approximately 60° F. By comparison, a typical 28% UAN solution contains 28% nitrogen by weight (28-0-0) and has a salting-out temperature of approximately 0° F. To store and handle a urea solution in early spring, it will be necessary to either reduce concentration to 20% N or less or add some N source that will maintain N content and lower salting-out temperature. Obviously, a reduced N concentration increases the need for storage capacity and transportation cost to the field, a problem the industry encountered several years ago in handling aqua ammonia as a direct application nitrogen source. In UAN solution, the industry combines urea and ammonium nitrate in a specific ratio to produce a 32% nitrogen solution with a salting-out temperature of approximately 32° F.

It should be apparent that producing a urea solution involves much more than simply dumping solid urea into a mixing vat of water. And, it is not easy to take the price of solid urea and arrive at a true cost for the end product delivered to the farm. Each dealer will have a different number. From a manufacturing standpoint, the decision to dissolve solid urea will probably be based on the price relationship between the delivered (in dealer storage) cost of the typical UAN nitrogen solution and the true cost of urea solution placed in dealer storage.

Although dealers must concentrate on cost of product as a key factor in the decision making process, they should not ignore the marketing aspect. A successful business depends heavily on having a solid base of satisfied customers. Most dealers take great pride in their ability to give prompt delivery service of a product that can be applied accurately and uniformly with a minimum of difficulty when field work is at a peak in the spring. Product quality and handling characteristics can be important. Since there are several possible urea solution formulations, each dealer will need to select the one that is best suited for the program that he promotes.

Although farmers want a product that is relatively trouble-free during application, their greatest concern is product performance, measured in terms of crop yield. Questions have been raised about how a urea solution will perform in agronomic comparison to a typical UAN nitrogen product.

These questions are not easy to answer for two reasons. One, it is possible to make several urea solutions, each having different apecifications and properties. Some contain all of the nitrogen content in the form of urea. Others contain combinations of urea, ammonium nitrate, ammonium sulfate and anhydrous ammonia in concentrations that vary with the manufacturing process. Two, nearly all of the current data base on nitrogen solution has come from experiments conducted with the typical UAN solution produced by basic U. S. nitrogen manufacturers. This material contains a combination of urea and ammonium nitrate with an ammonium nitrate/urea ratio of about 1.3. The pH of a typical UAN product is around neutral and it contains little or no free ammonia.

To simplify this discussion, the assumption has been made that a typical U. S. produced non-pressure nitrogen solution made with urea and ammonium nitrate and containing no more than 50% of the total N content in the form of urea is being compared with a solution that has substantially more than 50% of the total N content in the form of urea. The agronomic focus is on urea in a liquid form.

We need to set the record straight at the beginning of the discussion by stating that urea is an excellent source of fertilizer nitrogen. When applied to the soil, urea ($NH_2CONH_2$) begins to hydrolize in the presence of water ($H_2O$) and the enzyme urease, producing ammonia and carbon dioxide ($2\ NH_3 + CO_2$). In the next step, the reaction is similar to that which occurs when anhydrous ammonia is placed in the soil. If the soil has sufficient water, ammonium hydroxide is formed ($NH_3 + H_2O \longrightarrow NH_4OH$) which later dissociates into ammonium ($NH_4$) and hydroxyl ions (OH). If water is not present, the ammonia can, over time, pick up absorbed hydrogen ions held on exchange sites to form ammonium. The ammonium nitrogen formed from a urea application cannot be distinguished from the ammonium ions that come from N sources such as manure, soil organic fraction, legumes or other fertilizers unless it is tagged so that it can be identified by research procedures. At this point, one could say that N is N to a plant root that makes contact with it. The next step is nitrification, a process that takes place when nitrifying bacteria convert ammonium ($NH_4$) to nitrate ($NO_3$). All ammonium nitrogen ions can be converted to nitrate regardless of their origin.

Agronomists really only have two concerns about urea and both precede the formation of ammonium ions in the soil. The first is seldom given much attention today but it should not be ignored. In some manufacturing processes, urea is exposed to high heat. If this heat exceeds 200$^{o}$ F, some urea will convert to biuret:

$$\underset{\text{Urea}}{2\ CO(NH_2)_2} = \underset{\text{Biuret}}{NH_2\ CONHCONH_2} + \underset{\text{Ammonia}}{NH_3}$$

The rate of conversion accelerates as heat increases. Biuret only forms during the manufacturing process. It does not form when cooled urea is stored or applied to the soil as either dry or liquid product.

Most domestic producers manufacture a low biuret dry urea and nitrogen solution urea is introduced into the process as urea liquor that normally contains very little biuret. Because of this and the fact that most of the U. S. urea has been broadcast applied in recent years, U. S. agronomists have not had reason to be concerned about biuret. It may be time, however, to give it another look. Several years ago, scientists at the U.S.D.A. research center in Beltsville, Maryland reported that most domestic produced pelleted urea had a range of 1.3 to 1.5 percent biuret but some urea of foreign origin contained as much as 5.5 percent. If the low-quality foreign urea being dissolved contains a high concentration of biuret, the urea solution that is produced will also contain high biuret. This could cause a problem if the solution is used in formulation of a starter fertilizer that is going to be placed on or very near seed. It could also become a problem for preplant band application if seed is planted close to the band. Biuret will convert to ammonium but the conversion is much slower than that for urea and biuret may still be present several weeks after application. Biuret absorbed by plants is not considered to be a serious problem but some crops, such as citrus, have a fairly low tolerance and they have been known to show symptoms of biuret toxicity.

To my knowledge, there is no published information on the biuret content of urea currently entering the U. S. from foreign sources. It may not be a factor but it should be checked by the buyer and if it is high, application on or near the seed of field crops should be avoided.

The primary agronomic consideration for urea is volatilization loss. Volatilization loss, if it occurs, will nearly always be associated with a surface applied, non-incorporated application that does not receive 1/2 inch or more of rain or irrigation water within 24 hours after application. Loss takes place during the first step after application when urea is converting to ammonia before forming the ammonium ion. If the soil does not absorb the ammonia, it is lost into the air. Contrary to some beliefs, loss is only a sometimes event. To have loss, conditions must be favorable for rapid conversion of urea to ammonium. During rapid conversion, more free ammonia is produced than can be immediately trapped by the soil. A combination of certain soil characteristics, presence of water, presence of the enzyme urease and warm temperature are needed to trigger rapid conversion of urea to ammonium. Although warm temperature increases the probability of loss and the potential amount of loss, there can be some volatilization loss of ammonia when temperatures are cool. Dr. Regis Voss, agronomist, Iowa State University, was quoted in the Wallaces Farmer last spring, "Applying urea in the winter is risky. Some researchers believe there could be considerable loss of N, even at cool temperature."

Since volatilization loss is associated with urea, one must assume that as urea content of nitrogen solution is increased, the potential for volatilization loss of N may increase proportionately. This does not mean that urea solutions cannot be used successfully by the fluid industry but common sense should prevail. If you would not recommend the application of solid urea in a given situation, then don't apply a urea solution for the same reason. And, without benefit of research data or some personal experience, do not assume that urea solution will perform equally as well as UAN in all situations. When in doubt, do the farmer a favor by:

1. Incorporating all urea solution applications into the soil with the fertilizer applicator or a tillage implement. Injected bands are a good application choice.

2. If you cannot inject or incorporate, dribble band on the surface. Some data shows dribble band is superior to broadcast.

Do not apply urea solution on a soil surface that is covered by plant residues when temperature is warm. Residues can contain high amounts of the enzyme urease causing rapid urea conversion. Under conditions that were favorable for volatilization, some researchers have measured a 60 up to an extreme of 80% total N loss from a broadcast application of dry urea on non-tilled, residue covered experimental sites. Fluid urea may not be as volatile in a similar situation but N loss would still be serious.

There has been considerable interest by fluid dealers about the use of ammonium thiosulfate as an additive to UAN solution to retard the rate of urea conversion and reduce risk of volatilization loss. The key word is UAN. The research on this practice has been conducted with typical UAN solution and not urea solution. Research will be needed to determine if ammonium thiosulfate is effective when added to a urea solution and at what concentration.

No attempt has been made in this article to cite research data from studies conducted with either solid urea or UAN solution.

There is plenty of it available but one must question how applicable it is to urea solution. The final decision on whether to use fluid urea must rest with the dealer from an agronomic consideration standpoint. The dealer is the only one that knows the composition of the final product and how it will be applied. If solid urea is performing well in the area, then fluid urea applied in the same manner should perform equally as well, if not better. Uniformity of application will be a fluid advantage over dry. And, the fluid dealer has the upper hand over most dry dealers for band application. Liquid mix formulations will not segregate and fluids offer the opportunity to combine fertilizer and chemical applications. If a fluid urea product contains free ammonia, it will probably have a higher pH than typical UAN. This might make it necessary to use some caution in mixed liquid formulation and pesticide compatibility the first time these are tried.

Most of the decisions on dissolving urea concerning product cost, storage handling, etc., are strictly internal to the business. Agronomic considerations are external. Agronomic performance is judged by the farmer as he observes the crop appearance during the season, then totals up the harvest. The fluid industry has a solid base of farmers that are satisfied with the performance of UAN solution as a nitrogen source. It would be a serious mistake to jeopardize this confidence in nitrogen solution by careless application of urea solutions that may have only a short-term position in the industry.

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# PLAN FOR A GOOD YEAR AND YOU MAY GET ONE

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There is a South Dakota proverb that states "if you plan for a good year you may get one." It doesn't mean that profitability in farming is guaranteed. It never has been. What it does mean is that if we farm to the best of our ability and mother nature cooperates the opportunity for profit still exists. However, there is a second part to that proverb that states: "if you plan for a poor year you will get one." In other words if a farmer removes or reduces the inputs that have a significant effect on crop yield, failure to produce a profit is a certainty.

The key indicator of profitability in corn and soybean production is production cost/bushel. There are two major ways to lower production costs/bushel. The first is to reduce input costs. If such adjustments can be made without a dramatic effect on yield then those reductions provide sound management options. The second means to reduce production costs/bushel is by increasing yield. While this is not always a popular option in a time when surpluses are monumental the fact still remains that given the "rules of the game" that we face today we have little choice.

Lower production costs/bushel can be achieved with detailed planning, a knowledge of the factors which affect crop yield and common sense. Some of the factors which should be considered include hybrid or variety selection, tillage, rotation, soil drainage, planting date, row spacing, plant population, weed control, insect and disease control and soil fertility. Since a wide range of management guidelines exist throughout the region, I will restrict my comments to soil fertility.

## NITROGEN

With the strong relationship that exists between nitrogen application rate and corn yield, nitrogen is the key component in building a fertility program for high yields. When looking for places to trim production costs reducing nitrogen rates is not the place to start. In fact, when considering nitrogen fertilizer application rates we should borrow a term used in the dairy industry: "CHALLENGE FEEDING". Challenge feeding refers to challenging cows with high potential to produce even more milk by providing excess energy and protein. Corn yields can also be challenged by having more nitrogen available to the crop than what might be needed based on average yields.

What does the farmer gain from applying extra nitrogen? The first advantage is risk protection. In years with higher than average precipitation nitrogen loss by leaching or denitrification can be significant. In these years the extra nitrogen will provide some insurance against lost yield due to a shortage of available N. More important is that with favorable weather, improved management or genetic potential the farmer will have minimized the potential for nitrogen to be a limiting factor. Over time he will realize continually higher yields.

## PHOSPHORUS AND POTASSIUM

Agronomic and money management options exist for phosphorus and potassium fertilizer use if based on sound soil test information. Soils testing low to medium in phosphorus and potassium (<30 lb/A P or 200 lb/A K) provide limited flexibility. In this soil test range the probability and degree of response is large. Fertilizer use on these soils provides an excellent return on investment and should not be ignored. Two management strategies should be emphasized for these soils. First, some form of localized fertilizer placement, especially in reduced tillage situations, is preferred for corn. Small amounts of banded P and K can conservatively be credited with providing two to three times the yield response as equal amounts of broadcast P and K. For soybeans limited research data would seem to indicate little advantage to banding. In fact, a case could be made favoring broadcast applications. Second, in this soil test range fertilizer is most effective if applied on an annual basis. Frequently this is overlooked in corn-soybean rotations.

Soils testing medium to high (30-40 lb/A P and 200-300 lb/A K) generally demonstrate small or infrequent yield responses and provide several options. The first option is to continue to apply enough fertilizer to supply the crops needs and to gradually build the soils fertility status. This is a sound management strategy in years when capital is not limiting, but is not necessary in "tight money" years. The second option is to maintain the soils fertility status. The third option is to reduce or eliminate P and K fertilizer use. This strategy may provide a cost savings on a short term basis but the farmer must be aware that this decision is not without cost. If fertilizer is not applied soil tests will gradually decline. After a number of years the flexibility to apply fertilizer every second or third year or to broadcast fertilize as effectively as banding will be lost.

On very high testing soils (>40 lb/A P and 300 lb/A K) there is little if any advantage to applying fertilizer in excess of maintenance levels. In tight money years these soils are prime candidates for reduction or elimination of phosphorus and potassium fertilizer use. Soil tests will decline slowly but should be monitored until they reach a level where a higher probability of crop response exists.

WHO'S RESPONSIBLE FOR NITRATES IN GROUNDWATER?

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## INTRODUCTION

Within the last few years there has been considerable concern over the occurrence of nitrates ($NO_3$) in both ground and surface waters. This is especially significant since 50% of drinking water for the U.S. comes from groundwater supplies and this increases to 85% in the rural areas (CAST, 1985). The issue has at times become emotional and fingers have been pointed regarding the cause of nitrates in our water supply. So, what are the causes of this contamination and who is responsible?

A number of years ago, I remember the cartoon character Pogo responding to a somewhat similar situation with the statement, "WE HAVE MET THE ENEMY...AND HE IS US". That statement fits this question as well. We all directly or indirectly contribute to some degree to the occurrence of nitrate in our environment. To understand how $NO_3$ gets into groundwater, we must understand where it comes from and how it eventually reaches the groundwater.

## NITROGEN IN THE ENVIRONMENT

Nitrogen (N) is a basic part of our environment. The air we breathe is 78% nitrogen gas ($N_2$). Nitrogen accumulates in soils during the process of soil formation. Small additions from rainfall and plant and microbial fixations of $N_2$ gas from the atmosphere have accumulated in soils over thousands of years to produce soil organic matter. Many of our virgin prairie soils contained over 5000 lbs of this organically bound N when they were first plowed. Once a soil is tilled and crops are grown, organic matter content begins to decrease and organic N is released, which is used by the crops grown.

Inputs of N into an ecosystem occur whether it be from a native ecosystem, such as a forest or native prairie, an agro-ecosystem or a man-made ecosystem such as a city (Hergert, 1986). In natural ecosystems N is almost always in a short supply and internal N cycling is highly efficient, meaning that losses of N primarily due to leaching are low. In modern agriculture, however, with higher inputs of N the efficiencies of N use generally have decreased. Even if the overall percentage loss in an agricultural ecosystem were the same as in a natural ecosystem, the total quantity of $NO_3$ lost would be greater than any natural ecosystem because inputs are higher.

Although the majority of N in our soils exists in the organic form, plants take up N in the mineral form as either $NO_3$ or ammonium ($NH_4^+$). Most N used by plants is absorbed as the $NO_3^-$ ion. Plants do not take up organic forms of N. This means that organic sources of N must be converted to the $NO_3$ or $NH_4$ forms before they can be used by plants. Animal manures, compost, sewage sludge as well as legume crops are organic sources of N.

When any N is added to the soil as a fertilizer from organic or inorganic sources, it becomes a part of the soil N cycle. It is important to point out that plants cannot distinguish between the original source of the $NO_3$ or $NH_4$ they use. The total amount of $NO_3$ generated through the processes of the N cycle is not necessarily used by plants. When the supply is greater than the amount used by the plants, there is an increased potential for the accumulation of $NO_3$ in the soil and loss of N from the system.

Nitrate can be lost from the soil system by leaching, denitrification, volatilization of N gasses and immobilization or tieup by soil bacteria. From the standpoint of groundwater quality, leaching of $NO_3$ is the most important. Leaching is nothing more than the downward movement of water and $NO_3$-N through the soil with the soil water. Little or no leaching occurs if there is no downward movement of water. The potential for $NO_3$ leaching is not the same for all soils or all climates. Sandy soils are more permeable and will not hold very much water. Clay soils are finer in texture, have high water holding capacities and have a reduced tendency to leach.

## GROUNDWATER RECHARGE

The process of water moving or leaching through the soil leads to the recharge of our groundwater supplies. Because the processes of groundwater recharge are complex, the amounts of water and dissolved materials that enter the soil and eventually recharge the groundwater vary both seasonally and regionally. During the wet or cool seasons, recharge may occur and cause shallow water tables to rise. During dry or hot seasons, particularly with active plant growth, shallow water tables may be lowered by crop or plant water use. Thus, the potential for movement of chemicals into the groundwater varies with the time of application as well as the times and amounts of water penetration into the soil. Again, if the total amount of water going into the soil is not great enough, there will not be leaching of compounds.

Across the United States the amount of recharge and the depths of the water table vary with climate, soils, topography and geologic materials. In the more humid areas of the Eastern United States, water tables are commonly 5 to 30 feet below the surface. Groundwater recharge occurs almost every year. In the semi-arid regions where precipitation is lower, recharge may occur in some years and then in other drier years there may be none. In many parts of the semi-arid regions, however, irrigation is practiced to produce crops. Under irrigated situations, in many cases leaching does occur.

Currently there is not widespread enrichment of most groundwaters with $NO_3$-N that shows levels about the 10 ppm standard. Recent U.S. Geological Survey data show that almost every state has areas where $NO_3$ levels exceed EPA standards (Madison and Brunette, 1985). In ten states, 10% of the wells had $NO_3$-N greater than 10 ppm. However, recent studies in some states have shown localized areas where $NO_3$ concentrations have been increasing.

Nitrate, which moves downward through soils during the leaching or recharging process, is not necessarily all derived from N fertilizers. Much can come from the other aforementioned sources. Since the downward movement of $NO_3$ through the soils was taking place before the presence of man in this country and will continue, it is unreasonable to expect this movement can be stopped or eliminated. Man's alternation of his environment to produce food, however, can increase the rate of this movement and the magnitude of the losses (Hergert, 1986). There are, however, management practices that farmers can use to minimize the leaching of large amounts of $NO_3$ from soils.

## NITROGEN MANAGEMENT

Management of N to improve crop yields while reducing environmental contamination is highly site or location dependent and will vary with the crop grown (Randall, 1986). The purpose of the remainder of this article, however, is to present some of the management aspects of N, i.e., application rate, time of application, placement, nitrification inhibitors, and conservation tillage, and how these management tools can affect both crop yield and N loss to groundwater.

### Rate of Application

Using the proper application rate of N can have a greater effect on crop yield, N efficiency, economical return, and the environment than any other management tool. Application rates that are either too high or too low result in less profit to the farmer. To arrive at the optimum rate of N application the grower must consider the crop being fertilized and the productive capacity of the soil when setting a realistic yield goal. In addition, credits for N, which may be present due to previous legume crop, manure, residual $NO_3$ carried over from past fertilization, or N in the irrigation water, must be considered.

The effect of different N rates recommended by two soil testing laboratories for corn following soybeans in southern Minnesota is shown in Table 1. The "extra" 77 lb N/A did not result in significant or economical yield improvement but did contribute substantially to more $NO_3$ remaining in the soil profile at the end of the growing season. Some of the $NO_3$ moved below 4' by early November. By late April, over 25% of the $NO_3$ found in the 0-6' profile in November was not present. In addition, $NO_3$-N amounts in the 4-6' zone were 40% lower in April than in November.

Table 1. Corn yield and residual nitrate-N remaining in the soil profile as affected by N rate.

| N rate | Corn yield | Fall '85 Depth (feet) 0-6' | Fall '85 4-6' | Spr. '86 0-6' | Spr. '86 4-6' |
|---|---|---|---|---|---|
| lb N/A | bu/A | $NO_3$-N (lb/A) | | | |
| 160 | 162 | 178 | 38 | 129 | 31 |
| 237 | 165 | 284 | 62 | 210 | 54 |

Randall (unpublished data)

Results from another study conducted at the University of Minnesota Southern Experiment Station at Waseca show the effects of residual $NO_3$-N in the soil profile on corn yield and $NO_3$-N concentrations in the tile water (Table 2).

In this study annual rates of 0, 100 and 200 lb N/A were applied to continuous corn over a three-year period. The first two years were extremely dry and yields did not exceed 75 bu/A. Consequently residual $NO_3$-N remaining in the 0-3' profile at the end of the second year (1976) ranged from 43 lb/A with no N applied to 241 lb/A with the 200-lb rate. Above normal rainfall in the third year (1977) resulted in tile line drainage that averaged 58 mg $NO_3$-N/L with the 200-lb rate with no increase in corn yield over the 100-lb rate. It should be emphasized that $NO_3$-N concentrations averaged greater than 10 mg/L in the tile drainage water from these high organic matter soils (5 to 6%) even when no N was applied. These results indicate that substantial amounts of $NO_3$ can accumulate in these soils under dry conditions and then are highly susceptible to leaching.

Table 2. Residual nitrate-N, corn yield and average $NO_3$-N concentration in tile water as affected by N rate.

| Annual N rate | Residual[1/] $NO_3$-N in top 3' | 1977 Yield | Avg. $NO_3$N[2/] concentration in tile water |
|---|---|---|---|
| lb/A | lb/A | bu/A | mg/L |
| 0 | 43 | 94 | 13 |
| 100 | 125 | 146 | 41 |
| 200 | 241 | 146 | 58 |

Randall (unpublished data)
1/ October, 1976
2/ Flow-weighted average during 1977

Additional studies were conducted by Jokela (1985) on a Mount Carroll silt loam in Goodhue County and a Webster clay loam in Waseca County to determine the effect of N rate and time of application on fertilizer N (FN) uptake by the plant. He used a tagged N source (15-N) which allowed him to also measure FN in the soil and the uptake of the FN in the succeeding year. Results shown in Table 3 indicate greater percent recovery of the FN by the corn when applied at the lower rates but slightly greater recovery of FN in the soil at the higher rates of application. Total percent recovery favored the lower N rates and averaged slightly over 80%. Recovery of the residual FN (that remaining in the soil plus that returned to the soil in the stover) by the corn in the succeeding year was very small and was not affected by N rate.

Table 3. Fertilizer N recovered in the corn and soil in the year of application and by the corn in the year following application as influenced by N rate.

| N rate | Plant | Soil | Total | Recovery from soil in following year |
|---|---|---|---|---|
| lb N/A | -------- | % recovered | ---------- | % |
| | | Goodhue Co. | | |
| 67 | 51 | 32 | 83 | 5 |
| 134 | 40 | 34 | 74 | 7 |
| | | Waseca Co. | | |
| 89 | 42 | 37 | 81 | 1 |
| 178 | 35 | 44 | 79 | 1 |

Jokela, 1985

Investigations using 15-N labeled FN were conducted at Waseca to study the long-term uptake of FN from one 180 lb/A application of labeled N followed by annual applications of non-labeled N. Recovery of the FN by the corn averaged 37% in the year of application, fell markedly to less than 4% one year after application, and continued to fall to 0.4% four years after application (Table 4). Even in the year of application less than one-half (46.5%) of the N in the plant was derived from the fertilizer, which indicates that a substantial amount was coming from the soil. One year after FN application only 4.3% of the N in the corn was from the previous year's fertilizer. These data shown in Tables 3 and 4 indicate that a substantial amount of FN is being either incorporated into soil organic matter or remains as mineral N ($NO_3$ or $NH_4$), which is susceptible to loss through leaching or denitrification. But, plant uptake of this FN in succeeding years is relatively small.

Table 4. Recovery and uptake of FN by the corn plant in years following FN application at Waseca.

| Year after 15-N fertilization[1/] | FN recovery by the plant | Total plant N derived from 15-N |
|---|---|---|
| | % | % |
| 0 (15-N applied) | 36.8 | 46.5 |
| 1 | 3.9 | 4.3 |
| 2 | 2.0 | 2.1 |
| 3 | 1.1 | 1.3 |
| 4 | 0.4 | 0.5 |

Randall et al. (unpublished data)
[1/] N applied at a rate of 180 lb N/A each year.

## Time of application

Time of N application is important in increasing N efficiency and reducing potential N loss because a shorter time interval between fertilizer application and maximum crop uptake reduces the probability of loss due to either leaching or denitrification. For this reason, many corn growers throughout the Corn Belt are returning to spring and early summer applications.

Studies conducted at the Southern Experiment Station using ammonium sulfate clearly show both a yield and environmental advantage for the spring preplant application compared to the late-fall, plowed down application (Table 5). Corn yields over the five-year period were increased by 15 and 5% with spring application at the 120-lb and 180-lb rates, respectively. Spring application of N also reduced $NO_3$ losses to the tile lines by about 30%. Continuous soybeans lost as much $NO_3$ in the tile water as continuous corn with 180 lb N/A.

Table 5. Corn and soybean yields and $NO_3$-N lost through the tile lines as influenced by N rate and time of application at Waseca.

| Crop | N Treatment: N rate | N Treatment: Time | Five-year Avg. Yield | Four-year total $NO_3$-N lost in tile lines |
|---|---|---|---|---|
| | lb/A | | bu/A | lb/A |
| Corn | 0 | ---- | 66 | 28 |
| Corn | 120 | Fall | 130 | 107 |
| Corn | 120 | Spring | 150 | 75 |
| Corn | 180 | Fall | 159 | 136 |
| Corn | 180 | Spring | 167 | 106 |
| Soybeans | 0 | ---- | 44 | 119 |

Randall (unpublished data)

## Placement

Compared to anhydrous and aqua ammonia, dry and solution forms of N have had the flexibility of either being surface-applied or injected. Recent evidence, however, does point toward greater efficiency with the injection or deeper incorporation of these materials, especially when conditions are dry.

The data presented in Table 6 show no difference among N sources when applied preplant to continuous corn grown in a ridge-plant system. However, a 12 bu/A advantage was shown for anhydrous ammonia compared to urea when sidedress-applied at the 8-leaf stage. Both the urea and the UAN were applied to the soil surface and cultivated in to a 1 to 3" depth. The reason for this yield difference was thought to be positional unavailability due to only 1.5" of rain in the 4-week period following the sidedress application. Apparently, this amount of rain was not sufficient to nitrify the urea and UAN and move it down into the active rooting zone.

Table 6. Corn yield as influenced by time of application, N source and placement at Waseca.

| Application time | N Source | Yield 1/ |
|---|---|---|
| | | bu/A |
| Spring, Preplant | UAN | 154 |
| Spring, Preplant | Urea | 156 |
| Spring, Preplant | AA | 156 |
| Sidedress (8-lf stage) | UAN 2/ | 151 |
| Sidedress (8-lf stage) | Urea 2/ | 146 |
| Sidedress (8-lf stage) | AA | 158 |

Randall, 1982

1/ Averaged over 75 and 150 lb N/A rates

2/ Surface-applied and cultivated in

In another study with conventional moldboard plow tillage, corn yields were decreased with split applications when two-thirds of the N was sidedressed at the 8-leaf stage as UAN (Table 7). Injection of anhydrous ammonia at that stage consistently improved yields over the surface-applied UAN. A rain of 0.55" occurred 5 days after application and incorporated the UAN but was not followed by additional rain for over 3 weeks. Again, the sidedressed, surface-applied N was thought to be positionally unavailable compared to the anhydrous ammonia which had been injected about 7" into moist soil.

Table 7. Corn yield as influenced by placement of split-applied N at Waseca.

| Total application | 1/3 Preplant | 2/3 Sidedress | Yield |
|---|---|---|---|
| lb N/A | --------- N Source | --------- | bu/A |
| 0 | --- | --- | 66 |
| 60 | UAN | AA | 120 |
| 60 | UAN | UAN[1/] | 114 |
| 120 | UAN | AA | 152 |
| 120 | UAN | UAN[1/] | 132 |
| 180 | UAN | AA | 157 |
| 180 | UAN | UAN[1/] | 145 |

Randall & Kelly, 1986
[1/] Surface-applied in a band

Results from these two separate studies conducted in different years strongly suggest that sidedress applications of N should be injected into the moist soil to guard against positional unavailability in dry years. Moreover, the fertilizer N that was not used by the plant and remains in the soil not only reduces the economic return to the grower but also increases the environmental risks.

Nitrification inhibitors

Nitrification inhibitors add an extra dimension to a N management plan. By slowing the conversion of $NH_4$ to $NO_3$, the materials often result in greater amounts of fertilizer N being kept in the upper root zone and available for plant growth. This has been especially true on coarse-textured soils where leaching can be significant. As a result, yields and N uptake have often been increased on these soils by nitrification inhibitors. Consequently, the potential for contamination of the groundwater by the fertilizer is reduced.

Results obtained by Malzer (1979) from urea applied to a coarse-textured soil indicate a consistent yield advantage with the inhibitor at N rates up through 240 lb/A when preplant applied (Table 8). Yield increases due to the inhibitor were not obtained at N rates over 120 lb/A with the split-applied treatments. Yields were maximized with the 180-lb, split-applied treatments. Assuming that the yield losses were due to N leached out of the rooting profile, one quickly sees the potential for nitrification inhibitors in minimizing environmental concerns on coarse-textured, irrigated soils.

Table 8. Corn yields as influenced by N rate, time of application, and nitrification inhibitor treatment on a coarse-textured soil.

| N treatment | N rate (lb/A)[1/] 0 | 60 | 120 | 180 | 240 |
|---|---|---|---|---|---|
| | Yield (bu/A) | | | | |
| **Preplant** | | | | | |
| No Inhibitor | 59 | 89 | 105 | 136 | 170 |
| Inhibitor | | 119 | 150 | 169 | 181 |
| **Split application[2/]** | | | | | |
| No Inhibitor | | 117 | 167 | 191 | 191 |
| Inhibitor | | 127 | 181 | 191 | 190 |

Malzer, 1979

1/ As urea
2/ Split = 1/6 - preplant, 1/6 - 12 to 18" plant height, 1/2 - 30 to 36" plant height, and 1/6 - tasseling.

## Conservation tillage

Conservation tillage practices are becoming commonplace for a number of reasons, one of which is to reduce water runoff and subsequent erosion. It then follows that a greater proportion of the precipitation will infiltrate into the soil and perhaps percolate thru the soil. In many cases, it is thought that as the volume of percolating water increases, the liklihood of $NO_3$ leaching increases. For this reason some speculate that conservation tillage may in fact increase $NO_3$ losses to the groundwater. Data to address this hypothesis are limited.

Tile drainage plots at the Southern Experiment Station have been monitored to determine the effect of primary tillage on the $NO_3$-N concentrations and losses in the tile water, $NO_3$ accumulation in the soil profile, and crop yield. Nitrogen applied at 180 lb N/A as ammonium nitrate has been spring-applied annually to continuous corn on this clay loam site. Data from the 4-year period (1982-85) indicate little difference between the moldboard plow and no tillage systems for either total tile drainage or $NO_3$-N losses (Table 9). Additional years will be needed to determine if this effect changes over time. Moreover, numerous studies will need to be conducted over a wide range of soil permeability levels with various tillage systems before this question is answered satisfactorily.

Table 9. Effect of primary tillage on corn yield, tile line drainage and $NO_3$-N lost through the tiles from 1982-1985.

| Parameter | Tillage: Moldboard Plow | No Tillage |
|---|---|---|
| Avg. grain yield (bu/A) | 132 | 124 |
| Total tile discharge (acre-inches) | 41 | 44 |
| Total $NO_3$-N lost in tile (lb/A) | 88 | 98 |

Randall & Kelly, 1986

## SUMMARY

So, who is responsible for $NO_3$ in our groundwater? It's quite obvious that we all are but that intensive agriculture plays a major role. If we are to maintain a "cheap food policy", $NO_3$ in ground and surface waters will be part of the cost of doing business. Policy makers will need to weigh carefully the impacts of less intensive agriculture on the economy of rural America and the cost of food when assessing, interpreting and governing the occurrence of $NO_3$ in our water supplies. In the meantime, we know that N management practices can inflict a strong influence on both water quality and crop production economics. Using the proper rate of N probably exerts the greatest leverage. However, other management factors such as application time, placement, $NO_3$ soil test, nitrification inhibitors, and primary tillage methods also impact on N efficiency. The relative importance of these factors is highly dependent on the soil, crop grown, and climatic factors.

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CORN ROOTWORM MANAGEMENT IN CONTINUOUS AND FIRST-YEAR CORN

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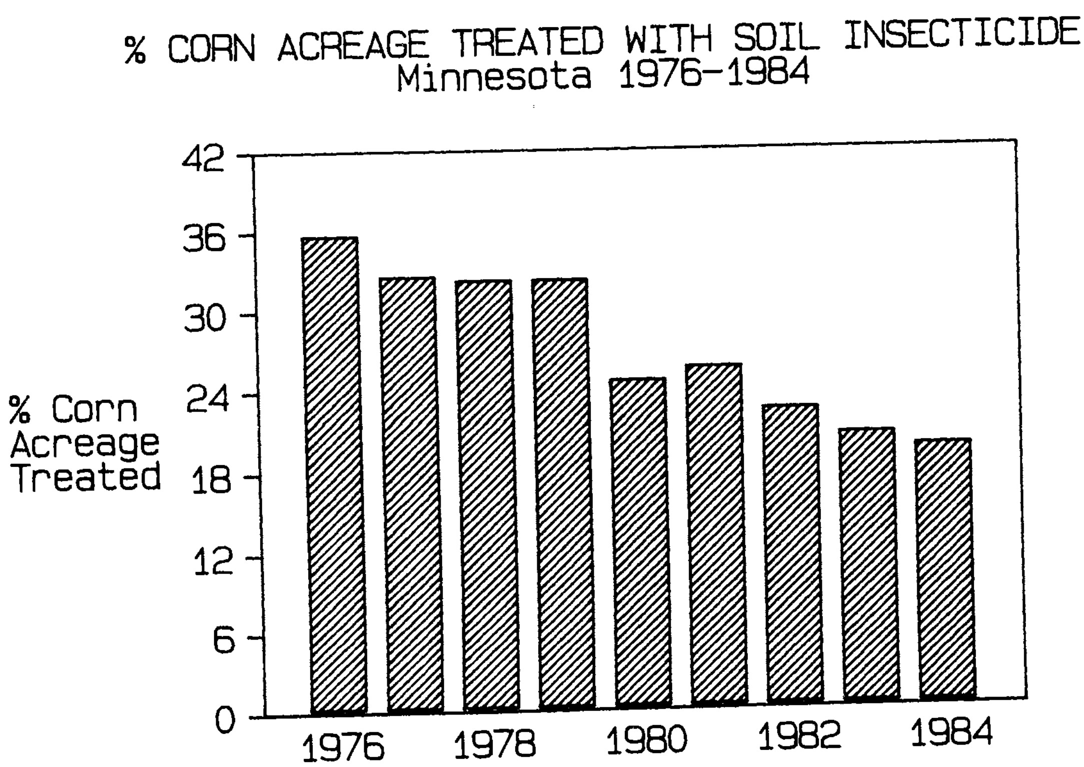
## INTRODUCTION

The combined strategies of crop rotation and soil insecticides in continuous corn usually limit corn rootworm damage quite effectively. Over the last 10 years, corn rootworm management strategies have shifted in favor of crop rotation as its many economic benefits became widely known. Consequently, soil insecticide use has steadily declined (Fig. 1). The need to trim input costs in farming operations is causing farmers to question further the necessity of soil insecticides. Meanwhile, the appearance of corn rootworm problems in corn/soybean or corn/wheat rotations is causing some farmers to increase their use of soil insecticides. In both of these cases, the goal is to use soil insecticides only when economically justified and to choose the most cost-effective insecticide for the job. This report contains information on soil insecticide performance and management of corn rootworms in first-year corn. Hopefully, the information will help you manage your soil insecticide inputs more efficiently while reducing unnecessary damage and yield loss.



## CORN ROOTWORM STATUS IN 1986

Corn rootworm populations have benefited substantially from the mild winters of 1984-1985 and 1985-1986. Populations statewide have increased from 1.92 beetles per plant in 1984 to 2.14 in 1985 to 2.78 in 1986. The mild winters have also favored a resurgence of western corn rootworms (WCR), which are less winter hardy but more destructive than northern corn rootworms (NCR), in areas with a large proportion of continuous corn. In SE Minnesota, the proportion of WCR in the population has increased steadily: 20% - 1984, 28% - 1985, 38% - 1986. The warm springs and rapid crop development have also accentuated corn rootworm damage. Unlike growing conditions in 1985 that did not favor brace root formation, growing conditions in 1986 favored prolific brace root formation. Sufficient moisture all season and excellent brace root development minimized yield and lodging effects of corn rootworm damage.

## INSECTICIDE PERFORMANCE IN 1986

The performance of soil insecticides was evaluated at four locations in Minnesota: Morris, Lamberton, Waseca, Rosemount. In contrast to previous years where all labelled insecticides appeared at each site, Rosemount was used primarily to evaluate experimental insecticides. Data from Rosemount will be used only to illustrate the performance of promising insecticides. and will not be used for calculation of performance consistency.

Corn rootworm pressure was quite variable but generally less severe than in previous years. Root damage did not exceed a 3.0 on the Iowa 1-6 rating system at either Morris or Waseca. Corn rootworm populations have been generally low at Waseca over the last 3 years. At Morris, low pressure reflects the combination of low population levels, excessive moisture and delayed crop development. For these reasons, only data from Lamberton and Rosemount will be presented. Mean root ratings for each insecticide at Lamberton and Rosemount are presented in Tables 1 and 2, respectively.

Promising unlabelled insecticides include the following:

| Insecticide | Class | Company |
|---|---|---|
| Apache 20G | organophosphate | FMC |
| CGA 12223 20G | organophosphate | Ciba-Geigy |
| Fortress 15G | organophosphate | Dupont |
| Lance 15G | carbamate | BASF |
| PP-993 1.5G | pyrethroid | ICI Americas |

Whether or not any or all of these insecticides will be labelled for corn rootworm and their relative role in the corn insecticide market remains to be seen. However, the potential increase in product selection and diversity seems encouraging.

At Lamberton all insecticides significantly reduced root damage below acceptable limits, a root rating = 3.0. At Rosemount all insecticides also significantly reduced root damage compared to the untreated check. In contrast to Lamberton, only 3 insecticides (Apache 20G, Furadan 15G, and Counter 15G) reduced root damage below acceptable limits. Note, however, that root damage at Rosemount occurred very early affecting only the first few whorls of secondary roots and leaving the later root whorls and brace roots undamaged. Since the initial secondary root system has fewer and smaller roots, a root rating 3.0 at Rosemount would not exhibit as much damage as a rating of 3.0 on a normal root system.

Table 1. Effectiveness of soil-applied insecticides against northern corn rootworms at Lamberton, Minnesota.

| Insecticide | Rate (lb ai/acre) | Placement | Root rating (1-6 scale) |
|---|---|---|---|
| ?Fortress 15G | 0.80 | F | 1.85a |
| ?PP 993 1.5G | 0.10 | F | 2.13ab |
| ?Fortress 15G | 0.60 | F | 2.15ab |
| *Counter 15G | 1.00 | F | 2.18ab |
| *Counter 15G | 1.00 | IF | 2.23ab |
| ?Lance 15G | 1.00 | F | 2.25abc |
| ?CGA 12223 20G | 0.50 | F | 2.38 bcd |
| *Thimet 20G | 1.00 | F | 2.41 bcd |
| Broot 15GX | 1.00 | F | 2.43 bcd |
| Lorsban 15G | 1.00 | F | 2.45 bcd |
| *Dyfonate 20G | 1.00 | R | 2.58 bcd |
| ?Lance 15G | 0.75 | F | 2.59 bcd |
| *Furadan 15G | 1.00 | F | 2.71 cd |
| *Dyfonate 20G | 1.00 | F | 2.73 cd |
| *Mocap 15G | 1.00 | R | 2.79 cd |
| Check | ---- | -- | 3.26 e |

Placement is coded as follows: F = ahead of presswheel, R = behind presswheel, IF = in furrow.
Means followed by the same letter do not differ significantly ($p<0.05$, DMRT).
? Not currently labelled on corn.
* Restricted-use insecticide.

Table 2. Effectiveness of soil insecticides in preventing damage by northern and western corn rootworms. Rosemount, Minnesota, 1986.

| Insecticide | Rate (lb ai/acre) | Root rating (1-6 scale) |
|---|---|---|
| ?Apache 20G | 0.75 | 2.53a |
| ?Apache 20G | 1.00 | 2.66ab |
| *Furadan 15G | 1.00 | 2.74abc |
| *Counter 15G | 1.00 | 2.86abc |
| *Dyfonate 20G | 1.00 | 3.04 bcd |
| ?Fortress 15G | 0.80 | 3.06 bcd |
| Lorsban 15G | 1.00 | 3.09 bcd |
| ?CGA 12223 20G | 0.50 | 3.15 cd |
| ?Fortress 15G | 0.60 | 3.34 de |
| Lorsban 15G | 0.50 | 3.69 e |
| Check | ---- | 4.59 f |

All treatments applied at planting behind the presswheel.
? Not currently labelled on corn.
* Restricted-use insecticide.
Means followed by the same letter do not differ significantly ($p<0.05$, DMRT).

CONSISTENCY OF CORN ROOTWORM INSECTICIDE PERFORMANCE

Corn rootworm insecticides vary in their performance from year to year and from location to location depending on corn rootworm population pressure, weather, crop development, soil characteristics, tillage, and weed populations. The ability of an insecticide to consistently maintain root ratings below the economic threshold (3.0) is an extremely important attribute. Consistency should be considered along with price and pest spectrum when selecting a corn rootworm insecticide. Consistency of each insecticide performance during recent years is presented in Table 3.

Table 3. Consistency of corn rootworm insecticide performance in Minnesota, 1977-1986, as measured by the proportion of trials where the insecticide maintained root ratings below a 3.0 (Iowa 1-6 rating scale).

| Insecticide | # Ratings < 3.0 / # Trials | % |
|---|---|---|
| Counter 15G | 25/26 | 96 |
| Thimet 20G | 24/25 | 96 |
| Broot 15GX | 22/23 | 96 |
| Dyfonate 20G | 21/25 | 84 |
| Furadan 15G | 21/26 | 81 |
| Mocap 15G | 19/25 | 76 |
| Lorsban 15G | 16/25 | 64 |
| Untreated check | 8/26 | 31 |

## SITUATION FOR CONTINUOUS CORN IN 1986

Adult corn rootworm populations vary considerably from field to field depending on relative crop phenology and cropping history. The best way to assess the need for a soil insecticide in continuous corn is to scout the field weekly during August. A general rule of thumb, or static threshold, is to treat the field if adult beetles average between 1 and 5 beetles per plant. Crop rotation is recommended when adult populations exceed 5 per plant and no insecticide is needed if populations are below 1 adult per plant.

Two problems confound the treatment decision. First, WCR are more aggressive feeders as larvae and more prolific egg producers than NCR. An approximation that can be used to compensate for changing ratios of WCR:NCR is to assume 1 WCR equals 2 NCR. Second, the current static threshold of 1 beetle per plant was developed for the WCR. In Minnesota, the climate and cropping practices favor the NCR. As presented in Table 4, WCR comprise only ca. 10% of the beetles. Consequently, the threshold may be too conservative, resulting in unneccessary insecticide use. Future research on damage and population vs field history and economic thresholds tailored to Minnesota conditions are needed to improve decisions about soil insecticide use.

The Minnesota Department of Agriculture - Plant Industry Division annually surveys corn rootworm populations throughout the southern 2/3 of Minnesota in early August. The results of this survey are presented in Table 4. Adult populations increased substantially or remained constant throughout most of Minnesota. Adult populations in all districts except the C and EC are well above threshold level. Clearly populations and the probability for damage in untreated fields are high throughout most of the state. If a field was not scouted last August, a soil insecticide is highly recommended for 1987.

Table 4. Corn rootworm adult beetle survey (Aug. 1-13) in continuous corn in Minnesota. Data supplied by Minnesota Department of Agriculture - Plant Industry Division.

| District | No. Fields | CRW beetles/plant 1985 | 1986 | Ratio NCR:WCR | % Lodging |
|---|---|---|---|---|---|
| WC | 11 | 2.12 | 4.57 | 89:11 | 1.5 |
| C | 20 | 1.93 | 1.43 | 99: 1 | 0.0 |
| EC | 18 | 1.03 | 0.85 | 95: 5 | 0.0 |
| SW | 27 | 1.33 | 4.17 | 96: 4 | 2.0 |
| SC | 29 | 1.90 | 2.86 | 96: 4 | 0.0 |
| SE | 38 | 3.18 | 3.22 | 62:38 | Trace |
| State average | | 2.14 | 2.85 | 90:10 | 0.6 |

## NCR DAMAGE TO FIRST-YEAR CORN

Isolated occurrences of corn rootworm damage in corn/soybean and corn/small grain rotations has been observed in Minnesota over the last 15 years. Although some damage to a few fields was expected in 1985, the magnitude of the problem was completely unexpected. I estimate that over 150 fields suffered damage sufficient to produce lodging problems. Surveys of affected farmers (N=60) indicated 90% had never noticed the problem in previous years. Lodged acreage comprised from 3 to 95% of the field, averaging 37%. Preliminary evidence quickly pointed to NCR as the cause of the problem. Adult populations in these fields dramatically exceeded the normal levels expected for first-year fields (<.5 beetle per plant). Adult counts averaged 5.4 beetles per plant, ranging from 2.8 to 12.5 beetles per plant. Approximately 97% of the adults were NCR.

Possible explanations for NCR problems in first-year corn center on egg laying in the previous crop or egg carryover from the last corn crop. The term "extended diapause" is used to describe the NCR egg's ability to successfully overwinter more than one winter. Recent research on eggs gathered from Minnesota beetles indicate ca. 40% of eggs in corn/soybean areas can hatch the second year. In contrast, only 11% of the eggs gathered from adults in continuous corn areas can hatch the second year. Review of field histories from affected fields strongly points to extended diapause as the most likely explanation. For example, 97% of the problem fields in 1985 were planted to corn. Recall the 1983 PIK/set aside program. If egglaying in noncorn crops were the answer, I'd expect a greater variation in 1983 crop histories including set aside. Perhaps the most convincing evidence comes from fields with a split history of set aside and corn in 1983. Of 9 fields with verified NCR damage in 1985, none exhibited lodging or significant corn rootworm damage in the part that was set aside in 1983.

## STATUS OF FIRST-YEAR CORN ROOTWORM PROBLEMS IN 1986

After the explosive increase in first-year problems with NCR in 1985, it was natural to wonder what 1986 would hold for us. If crop rotation actually select for extended diapause, the problem should predictably persist in 1986. However, the problem is not always apparent. Remember that NCR damage is only visible when lodging occurs. Damage can occur and for many reasons lodging may not occur. Thus, lodged fields represent the "tip of the iceberg". In 1985, conditions (damage, poor brace root formation, storms) were favorable for lodging to occur. In 1986, excellent brace root formation and adequate moisture obscured lodging and yield response to NCR damage. I received scattered reports of lodging in first-year corn but the magnitude of the "visible" problem declined substantially from 1985. Root damage at my first-year corn research sites was sufficient to produce lodging problems under 1985 conditions. The bottom line is that the problem is still here and not temporary in nature.

## SOIL INSECTICIDES ON FIRST-YEAR PROBLEM FIELDS

Research was initiated in 1985 to determine if the problem repetitively occurred in the same fields and if soil insecticides provided an economical solution to the problem. A total of 8 fields, 3 in 1985 and 5 in 1986, with a prior history of the problem were selected. In each field untreated and treated strips were alternated across the field by filling half of the planter's insecticide boxes with Counter 15G. Stand, root ratings, lodging, and yield were measured on selected strips. A summary of mean values for each treatment is presented by site in Table 5.

Table 5. Root damage, yield and percent lodging in first-year corn fields with strips treated with Counter 15G.

| | | Root Rating | | Yield (bu/acre) | | % Lodging | |
|---|---|---|---|---|---|---|---|
| Year | Site | Counter | Check | Counter | Check | Counter | Check |
| 1985 | Mn. Lk. 1 | 2.45 | 3.13 | 151.3 | 153.4 | 48.2 | 62.5 |
| | Mapleton | 2.16 | 2.42 | 170.8 | 167.4 | 0.0 | 0.0 |
| | Janesville1 | 2.56 | 2.86 | 180.6 | 175.3 | 27.6 | 48.7 |
| | Average | 2.39a | 2.80b | 167.6a | 165.4a | 25.3a | 37.0a |
| 1986 | Mn. Lk. 1 | 2.15 | 2.86 | 159.2 | 155.0 | 1.3 | 29.3 |
| | St. Clair | 2.17 | 3.19 | 144.2 | 143.0 | 0.6 | 2.7 |
| | Waldorfr | 2.33 | 2.96 | 164.6 | 162.8 | 1.5 | 22.5 |
| | Mn. Lk. 2 | 2.94 | 3.51 | 148.0 | 145.7 | 1.5 | 14.5 |
| | Janesville2 | 2.58 | 3.00 | 174.0 | 156.5 | --- | ---- |
| | Average | 2.43a | 3.15b | 158.0a | 152.6a | 1.2a | 17.3a |

Within each year and variable, means followed by the same letter do not differ significantly ($p<0.05$, DMRT).

NCR damage was evident each year in fields with a previous history of the problem. Root pruning was commonly observed and root ratings in most fields averaged near 3.0 (= 1 root pruned to within 1" of the stalk). At these damage levels, lodging and yields begin to be affected. Surprisingly, severe root damage like that commonly observed in lodged fields in 1985 was not present in any of the research fields. Counter 15G significantly reduced root ratings each year but did not significantly affect yield or lodging. A trend for Counter 15G to reduce lodging and increase yields is evident but not significant with such small sample sizes within years.

A summary of soil insecticide benefits analysed across years and sites is presented in Table 6. Overall, Counter 15G significantly reduced root ratings and lodging but only approached significance in increasing yields. Yield response to insecticide averaged only 4.2 bu/acre. Assuming a cost of $12.72/acre for Counter 15G (8.7 lb/acre X $1.46) and corn prices of either $1.75 (loan rate) or $1.35 (market price), the breakeven point for a farmer would be ca. 7.3 bu/acre (program) or ca. 9.4 bu/acre (market). The average yield benefit with the insecticide (4.2 bu/acre) is substantially below the breakeven point. The "average" farmer would have lost $5.36/acre (program) or $7.05/acre (market). Only the farmer in 1 of the 8 trials would have used the soil insecticide profitably. Clearly, previous history of the problem is not a reliable indicator of problem severity or profitable use of the insecticide input.

Table 6. Summary of soil insecticide benefits in first-year corn fields with a previous history of severe corn rootworm damage, 1985-1986.

| Treatment | Root rating (1-6 scale) | % Lodging | Yield (bu/acre) |
|---|---|---|---|
| Counter 15G | 2.42 | 11.5 | 161.6 |
| Untreated check | 3.02 | 25.8 | 157.4 |
| Benefit | -.60 | -14.3 | +4.2 |
| Range | (-.26, -1.02) | (0, -28.0) | (-2.1, +17.5) |
| Significance | .0004 | .011 | .084 |

ADULT COUNTS AS A PREDICTIVE TOOL

The evidence just presented indicates that NCR problems in first-year corn have little initial warning and that previous field history of the problem does not offer a reliable indicator of profitable insecticide use. In this situation, how can a farmer make a sound decision about insecticide use in first-year corn? One potential solution is to routinely monitor all corn fields for adult corn rootworms. Combined with good record keeping, these adult counts may serve as valuable guides for planning crop rotation and insecticide use.

To determine if adult counts have any predictive value, I examined root damage in 11 first-year fields scouted 2 years previously. Field locations and adult counts were generously supplied by Paul Miller, L $ M Consulting of Waseca. Preliminary evidence indicates a strong correlation (r=.73) between these adult counts and damage 2 years later. The data suggest that at least 3-4 NCR beetles per plant are required before damage exceeds a root rating of 3.0 (Iowa 1-6 scale) 2 years later. Additional data are required to determine if this relationship holds true and to generate a robust threshold that reflects variation in survival over 2 or more winters.

CROP ROTATION AS A MANAGEMENT STRATEGY

Despite the excitement over NCR problems in first-year corn, the fact remains that most fields escape the problem or do not suffer sufficient damage to be readily detected. Last year, I proposed that one solution in fields with a previous problem might be to lengthen the crop rotation. In addition to economically viable crop options, another possible problem has emerged with this option. Extended diapause means that NCR eggs can successfully overwinter 2 or more winters. Evidence surfaced this summer of a field extensively damaged 3 years after corn was last planted in the field. The field in Yellow Medicine Co. was split between set aside and corn in 1983, soybeans in 1984, wheat in 1985, and planted back into corn in 1986. To the row, damage (root rating >4) and severe lodging was only observed where corn was grown in 1983.

ACKNOWLEDGEMENTS

The research presented in this paper would not have been possible without the generous support of the people of Minnesota through the Minnesota Agricultural Experiment Station and the agrichemical companies whose products were evaluated in this research. In the first-year corn studies, I especially appreciate the cooperation of Paul Miller, L & M Consulting, and the farmers who offered their fields for study: Bill Daly, Steve Dimmel, Rick Hoehn, Joe Kluender, Ambrose Sonnick, Dan Stevermer, The Trahms, Danny Trio. Special recognition is extended to American Cyanamid for their support of NCR studies in first-year corn.

# HOP VINE BORER MANAGEMENT IN CONSERVATION TILLAGE

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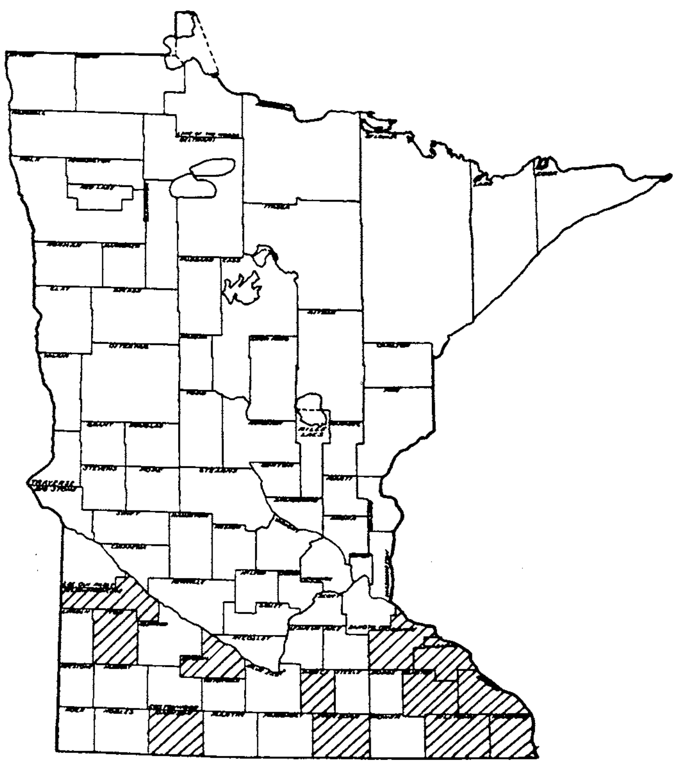
## INTRODUCTION

The hop vine borer (*Hydroecia immanis*), an obscure insect that gained notoreity in the late 1800s for its attraction to hops grown for the beer industry, is found in scattered areas throughout SC and SE Minnesota (Fig. 1). Traditionally regarded as a grass/hop specialist, this insect has successfully adapted to a grass/corn feeding style. Since the mid 1970s, this stem-boring noctuid caterpillar has caused severe, localized damage to corn in Minnesota, Wisconsin, Iowa, and Illinois.

Figure 1. Hop Vine Borer (*Hydroecia immanis* Guenee) distribution in Minnesota, based on larval records as of 1986.



## LIFE CYCLE

Eggs are laid each fall in the leaf sheaths of several grasses including smooth brome and quackgrass. Early in the spring, the larvae hatch and the first three or four stages feed in stems of the grass host. As the larvae grow in size, they abandon the grasses in search of more favorable hosts like wild hops or corn. Dispersing larvae attack corn stems below soil level, destroying the growing point or severing its connection to the roots. Above-ground symptoms include wilting central leaves ("dead-heart") and eventual death. It is estimated that 90-95% of the attacked plants die. The larvae, easily distinguished by brown/purple spots on each segment of the creamy white thorax and abdomen, reach up to 2 inches in length. Stand loss usually subsides in late June as the larvae pupate.

## THE MANAGEMENT DILEMMA

Persistent infestations create a management dilemma for farmers, especially on highly erodable fields under conservation tillage with continuous corn. This situation creates the ideal conditions for maximum damage. Soil conservation measures establish an abundance of oviposition sites including grass waterways and patches of sodforming weedy grasses such as quackgrass. Elimination of moldboard plowing and the restricted herbicide selection available in continuous corn severely limit the farmers ability to control these perennial grasses. Finally, soil insecticides are ineffective against this insect. Currently, the only way to manage the problem is to break the grass/corn cycle by either eliminating the grass (e.g. plowing waterways and quackgrass patches) or rotating crops. These alternatives can be environmentally and economically undesirable.

## 1985 AND 1986 RESEARCH

The purpose of our research was to evaluate the performance of several foliar insecticides (primarily pyrethroids) against the hop vine borer, document the economic impact of the insect, and the economic benefits of insecticide applications. Eight insecticides in 1985 and seven insecticides in 1986 were chosen primarily for their activity against cutworms. The insecticides were applied on May 28, 1985 and May 29, 1986 to plots measuring 6 rows X 20 ft. The plots were located along a fence line or railroad right-of-way in corn rows 2-7. Insecticides were broadcast in 17 gallons of water per acre when stand loss and dead-heart symptoms from migrating hop vine borers were noted in row 1. Corn was in the 3-4 leaf stage. Stand counts were made pretreatment and 14 days posttreatment in both years. Yields and final stand counts were taken in 1985 at physiological maturity.

## INSECTICIDE PERFORMANCE

Insecticide performance against the hop vine borer in 1985 and 1986 are presented in Tables 1 and 2, respectively. Compared to nearly complete control failures with soil insecticides, the moderate control levels achieved with pyrethroids are extremely encouraging. Pyrethroids reduced stand losses 57-78% in 1985 and 58-100% in 1986. Generally, organophosphates and carbamates appear to be less effective and more expensive than pyrethroids. Lorsban 4E provided mixed results with only 17% reduction in stand loss in 1985 vs. 78% in 1986.

Table 1. Insecticide performance against hop vine borer in 1985, as measured by percent stand loss and percent reduction in stand loss. Olmsted Co.

| Insecticide | Rate (lb ai/acre) | % Stand loss at 14 days | % Reduction in stand loss |
|---|---|---|---|
| *Pydrin 2.4E | 0.20 | 3.8 d | 78 |
| *Ambush 2E | 0.20 | 5.6 cd | 67 |
| ?Karate 1E | 0.025 | 6.3 cd | 63 |
| ?Baythroid 2E | 0.025 | 6.8 cd | 60 |
| *Payoff 2.5E | 0.08 | 7.3 cd | 57 |
| ?Larvin 3.2E | 1.00 | 8.9 bcd | 47 |
| Lorsban 4E | 1.00 | 14.0 bc | 17 |
| *Furadan 4F | 1.00 | 28.1a | 0 |
| Check | ---- | 16.9ab | -- |

* denotes restricted use insecticides.
? denotes unlabelled insecticides on corn.
Means followed by the same letter do not differ significantly (p<0.05, DMRT).

Table 2. Insecticide performance against hop vine borer in 1986, as measured by percent stand loss and the percent reduction in stand loss. Olmsted Co.

| Insecticide | Rate (lb ai/acre) | % Stand loss at 14 days | % Reduction in stand loss |
|---|---|---|---|
| ?Asana 1.9E | 0.05 | -1.4 b | 100 |
| *Pydrin 2.4E | 0.20 | 0.8 b | 93 |
| Lorsban 4E | 1.00 | 2.5 b | 78 |
| ?Spur 2E | 0.10 | 2.9 b | 74 |
| ?Ammo 2.5E | 0.10 | 3.5 b | 69 |
| ?Baythroid 2E | 0.025 | 4.8ab | 58 |
| *Pounce 3.2E | 0.20 | 5.3ab | 53 |
| Check | ---- | 11.3a | -- |

* denotes a restricted use insecticide.
? denotes an insecticide not labelled on corn.
Means followed by the same letter do not differ significantly (p<0.05, DMRT).

## COST EFFECTIVENESS OF CONTROL

Expected and actual yields plus relative yield loss are presented for the 1985 trial in Table 3. The untreated hop vine borer infestation reduced yields 33 bushels per acre or ca. 26%. Treatments appear cost-effective, particularly where farmers can restrict the area treated with insecticide by mapping infestation locations.

Table 3. Insecticide performance against the hop vine borer in field corn, as measured by relative yield loss. Olmsted Co. 1985.

| Insecticide | Rate (lb ai/acre) | Yield (bu/acre) Actual | Expected | Yield loss (bu/acre) | % |
|---|---|---|---|---|---|
| *Pydrin 2.4E | 0.20 | 114.5a | 114.9a | 0.4 b | 0.3 c |
| *Ambush 2E | 0.20 | 116.6a | 123.4a | 6.8 b | 5.2 c |
| ?Karate 1E | 0.025 | 116.6a | 118.6a | 2.1 b | 1.7 c |
| ?Baythroid 2E | 0.025 | 123.4a | 125.3a | 1.9 b | 1.6 c |
| *Payoff 2.5E | 0.08 | 112.2a | 118.4a | 6.2 b | 5.0 c |
| ?Larvin 3.2E | 1.00 | 103.4ab | 116.8a | 13.4 b | 12.8 bc |
| Lorsban 4E | 1.00 | 111.1a | 125.8a | 14.8 b | 11.5 bc |
| *Furadan 4F | 1.00 | 76.4 b | 113.6a | 37.1a | 34.7a |
| Check | ---- | 93.8ab | 126.9a | 33.2a | 26.1ab |

* denotes a restricted use insecticide.
? denotes the insecticide is not labelled on corn.
Means followed by the same letter do not differ significantly (p,0.05, DMRT).
Expected yield calculated by multiplying average ear size (0.00552 bu/ear) X pretreatment stand. This caluclation based on assumption that in the absence of hop vine borer all plants would yield equivalently.
Yield are corrected to 15.5% moisture.

## CONCLUSIONS AND RECOMMENDATIONS

1. Broadcast applications of pyrethroids significantly reduce but do not eliminate stand loss from hop vine borers.

2. Pyrethroids currently labelled on corn for cutworm control and suggested for hop vine borer control include fenvalerate (Pydrin 2.4EC), flucythrinate (PayOff 2.5E), and permethrin (Ambush 2E, Pounce 3.2E). These compounds should be applied at the high rate for cutworms.

3. Lorsban 4E may be effective against hop vine borer but contradictory results between 1985 and 1986 necessitate additional data before its performance can be adequately evaluated.

4. Insecticide application should be timed to larval movement from grasses. At field margins, look for early signs of hop vine borer attack (wilting, dead heart, stand loss) to time insecticide application. Within grassy areas of fields, apply the insecticide at spikingand again 10 days later. These timing guidelines are only suggestions based on field observations. More definitive recommendations will depend on further research.

5. Insecticide treatment can provide a cost-effective management tool for the hop vine borer, particularly if heavily infested areas such as quackgrass patches, fence rows and right-of-ways can be mapped for treatment the following year.

# EUROPEAN CORN BORER:
# STATUS AND INSECTICIDE PERFORMANCE IN 1986

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## INTRODUCTION

During the last three years European corn borer (ECB) populations have flucuated from record high levels in 1983 (212 borers/100stalks) to near record lows in 1985 (11 borers/100stalks). Dramatic flucuations in ECB populations levels lead to many questions: When will the next ECB outbreak occur? How can I tell if my field needs to be treated? What insecticides will provide the best or the most cost-effective control?

Understanding ECB population dynamics holds the key to predicting future outbreaks. Over the last 25 years, ECB populations have peaked on a statewide level ca. every 6-7 years (1963, 1970, 1977, 1983). While it is tempting rely on historical trends and predict an outbreak in 1989 or 1990, reliance in this prediction without understanding the causes of these population flucuation would be foolhardy. Populations flucuations represent the interaction of ECB with weather, crop development, varietal resistance, natural enemies, and cultural practices. Unfortunately, our knowledge of how these factors interact to produce populations flucuations is too limited for predictive purposes. Thus, the best safequard against unexpected ECB infestations and yield loss involves regular scouting and timely treatments if populations exceed economic thresholds.

## THE EUROPEAN CORN BORER IN 1986

Overwintering ECB populations were extremely low after the 1985 growing season. Despite excellent overwintering conditions (Recall that early snows kept the soil from freezing until mid to late winter), only widely scattered infestations reached economic levels during first generation in SE and WC Minnesota. Treated fields were typically the very earliest planted in an area and often irrigated. The general failure of more extensive infestations to develop reflects the interaction between low overwintering populations, early emergence of ECB adults, retarded crop development, and rainy weather. As in 1985, warm spring temperatures disrupted normal synchrony between ECB and corn by accelerating ECB development with respect to corn planting dates and development. The majority of corn, consequently, was too young to be attractive to ECB adults. Even when egg-laying took place on this young corn, survival was extremely poor because resistance levels were still high. For these reasons, first generation populations levels were usually noneconomic.

Second generation was surprisingly successful. Although the second adult flight was never very high, it was very extended and constant. Unseasonably cool temperatures during August may have enhanced the survival of second generation larvae and their damage by prolonging varietal maturation. Although the success of the second generation raised concerns about harvest losses, populations levels were never high enough to treat economically given the current farm economy. The high number of overwintering borers (Table 1), however, does suggest the potential for first generation infestations next summer.

First generation ECB populations in northern Minnesota were also lower than in 1985. As in 1983 and 1984, summer temperatures were sufficiently high to produce a partial second flight. This flight did not cause any economic damage to corn and reduced the overwintering population of borers.

Table 1. Results of Minnesota's fall survey for European corn borer, Oct. 13-31, 1986. Data supplied by the Minnesota Department of Agriculture - Plant Industry Division.

| District | % Plants infested | # ECB larvae per 100 plants | % broken stalks | % shanks infested | % ears on ground |
|---|---|---|---|---|---|
| WC | 55.8 | 105 | 3.5 | 11.3 | 0.33 |
| C | 42.8 | 73 | 1.8 | 9.8 | 0.33 |
| EC | 38.7 | 60 | 1.0 | 11.9 | 0.0 |
| SW | 52.8 | 80 | 3.2 | 7.2 | 0.0 |
| SC | 62.3 | 107 | 2.7 | 11.2 | 0.7 |
| SE | 59.5 | 103 | 2.7 | 8.6 | 0.15 |
| State Average | 52.0 | 88 | 2.5 | 10.0 | 0.25 |

INSECTICIDE PERFORMANCE IN NORTHERN MINNESOTA

The purpose of this research is to generate data on insecticide performance with sufficient reliability to use in economic threshold calculations. Since 1984, insecticide performance has been evaluated in both aerially applied and ground applied settings. During 1986, three aerial trials and 1 ground trial were conducted in northern Minnesota against first generation ECB. The performance of granular and liquid insecticides when aerially applied is presented in Table 2. Furadan 15G, Penncap-M 2F, and Pounce 3.2E generally provided the best control at all three sites. Note that a one week delay in Pounce 3.2E application at Twin Valley reduced its relative effectiveness. Pounce 1.5G provided eratic control ranging from 30 to 60% when aerially applied. Eratic performance, in view of excellent permethrin granule performance in ground trials, suggests a problem in calibrating and uniformly applying the small granules.

Table 2. Effectiveness of aerially applied insecticides against first generation ECB in northern Minnesota, 1986.

| Insecticide | Rate (lb ai/acre) | Tunnels per 10 infested plants | | |
|---|---|---|---|---|
| | | Twin Valley | Gentilly | Crookston |
| Furadan 15G | 1.00 | 6.0a | 3.7a | 12.0ab |
| Penncap-M 2F | 2X 0.25 | 10.0ab | 4.0a | --- |
| | 0.50 | 10.7ab | 4.7ab | 4.7a |
| Pounce 3.2E | 2X 0.10 | 16.0 bc | 4.3ab | --- |
| | 0.15 | 15.5 bc | 5.0ab | 6.3a |
| Sevin XLR Plus | 2.00 | 14.3 bc | --- | --- |
| Lorsban 15G | 1.00 | 15.3 bc | --- | --- |
| Pounce 1.5G | 0.15 | --- | 6.3ab | 16.0 b |
| | 0.10 | --- | 10.7 cd | 13.3ab |
| Lorsban 4E | 1.00 | 21.7 c | 7.7 bc | --- |
| Pydrin 2.4E | 0.15 | --- | 11.7 d | --- |
| Check | ---- | 34.0 d | 15.7 e | 26.3 c |

[a] Due to delays in product availability, Pounce 3.2E was applied 1 week later than all other treatments at Twin Valley.
[b] Split applications were made 1 week apart.
Means followed by the same letter do not differ significantly ($p<0.05$, DMRT).

A summary of all aerial trials in 1985 and 1986 is presented in Table 3. In 1986 and over all aerial trials, Furadan 15G, Pounce 3.2E, and Penncap-M 2F consistently provided better than either Lorsban 4E or Pydrin 2.4E. For this reason, neither Lorsban 4E or Pydrin 2.4E are recommended for aerial application against first generation ECB. From an economic perspective, Pounce 3.2E and Penncap-M 2F offer control equivalent to Furadan 15G at substantially reduced costs. Although prices vary considerably, relative in-season costs (including a $2.50/acre application cost) during 1986 were estimated for Penncap-M 2F, Pounce 3.2E, and Furadan 15G at $6.88, $6.57, and $12.75 per acre, respectively. To illustrate the effect of relative treatment costs on economic thresholds, let's assume the following values hold next summer: yield = 90 bu/acre, price = $1.75/bu, % loss per borer = 5%, insecticide effectiveness = .75 (Table 3). Preventable loss (= yield X price X loss per borer X insecticide effectiveness) would be $5.91 /borer /plant. The economic threshold (= insecticide cost/preventable loss) would be .85, .90, and 2.16 borers/plant for Pounce 3.2E, Penncap-M 2F, and Furadan 15G, respectively. Note how the economic threshold rises with insecticide cost if all other factors (e.g. effectiveness) are constant.

Table 3. Summary of insecticide performance when aerially applied against first generation ECB in northern Minnesota, 1985-1986.

| | | Percent control | | | | | |
|---|---|---|---|---|---|---|---|
| | Rate | 1985 | | 1986 | | | |
| Insecticide | (lb ai/acre) | C | TV | C | TV | G | Avg. |
| Furadan 15G | 1.00 | 83.5 | --- | 54.4 | 82.4 | 76.4 | 74.2 |
| Pounce 3.2E | 0.15 | 82.5 | 74.1 | 76.0 | * | 68.2 | 75.2 |
| Penncap-M 2F | 0.50 | 81.0 | 70.7 | 82.1 | 68.5 | 70.1 | 74.5 |
| Lorsban 4E | 1.00 | 63.5 | 46.6 | ---- | 36.2 | 51.0 | 49.3 |
| Pydrin 2.4E | 0.15 | 59.3 | 41.4 | ---- | 25.5 | ---- | 42.1 |

* Data not included in summary because of 1 week delay in application.
Plot locations are abbreviated as follows: C - Northwest Expt. Stn., Crookston, G - Lanctot farm, Gentilly, TV - Christenson farm, Twin Valley.

One small-plot trial near Angus, Polk Co., evaluated the performance of both labelled and unlabelled insecticides against ECB in northern Minnesota. Results of this trial are presented in Table 4. The following insecticides provided control equivalent to the best insecticide: Ambush (2E, 1.5G), Baythroid 2E, Dyfonate 20G, Furadan (15G, 4F), Larvin 3.2E, Lorsban 15G, Penncap-M 2F, Pounce (3.2E 1.5G), and Pydrin 2.4E. These compounds provided at least 63% reduction in tunnels. Only Lorsban 4E did not differ significantly from the untreated check. All remaining insecticides provided marginal to fair reduction in tunnel number.

Table 4. Performance of granular and liquid insecticides against first generation ECB in a small-plot trial. Milo Carlson farm, Angus, Polk Co. 1986.

| Insecticide | Rate (lb ai/acre) | Tunnels per 10 infested plants | % Control |
|---|---|---|---|
| Ambush 2E | 0.15 | 6.25a | 82.4 |
| Ambush 1.5G | 0.15 | 7.50ab | 79.0 |
| Baythroid 2E | 0.025 | 9.25abc | 74.0 |
| Dyfonate 20G | 1.00 | 9.50abcd | 73.3 |
| Pounce 1.5G | 0.15 | 9.50abcd | 73.3 |
| Lorsban 15G | 1.00 | 9.63abcd | 73.0 |
| Larvin 3.2E | 0.75 | 10.25abcd | 71.2 |
| Pounce 3.2E | 0.15 | 10.50abcd | 70.5 |
| Furadan 4F | 1.00 | 10.50abcd | 70.5 |
| Furadan 15G | 1.00 | 11.33abcd | 68.2 |
| Pydrin 2.4E | 0.15 | 12.25abcd | 65.6 |
| Penncap-M 2F | 0.50 | 13.00abcd | 63.5 |
| Dipel 14G | 1.00 | 14.25 bcde | 60.0 |
| Diazinon 14G | 1.00 | 16.00 cde | 55.1 |
| Thimet 20G | 1.00 | 17.00 cde | 52.3 |
| Dipel 10G | 1.00 | 17.25 de | 51.6 |
| Sevin XLR Plus | 2.00 | 21.00 e | 41.1 |
| Asana 1.9E | 0.025 | 21.50 e | 39.7 |
| Lorsban 4E | 1.00 | 30.13 f | 15.4 |
| Check | ---- | 35.63 f | ---- |

Means followed by the same letter do not differ significantly ($p<0.05$, DMRT).

## INSECTICIDE PERFORMANCE IN SOUTHERN MINNESOTA

Isolated ECB populations reached economic thresholds in southern Minnesota, providing the opportunity to evaluate insecticide performance against first generation at one location in WC Minnesota. Two experiments examining the performance of granular and liquid formulations, respectively, were established in irrigated corn near Beardsley, Big Stone Co.. All granular insecticides significantly reduced the number of tunnels from the untreated check (Table 5). Control ranged from 55 to 89%. Only Dipel 14G did not provide control equivalent to the best compound. Three unlabelled compounds, the pyrethroids PP993 1.5G and Ambush 1.5G and the organophosphate Fortress 15G, worked very well, providing over 80% control. Performance of liquid insecticides against first generation ECB was more variable ranging from 30 to 91% reduction in tunnel number. The following insecticides provided control comparable to the best liquid: Baythroid 2E, Penncap-M 2F, Ambush 2E, Lorsban 4E, Pounce 3.2E, and Dipel ES. Two insecticides, Pydrin 2.4E and Asana 1.9E, failed to significantly reduce tunnel number when compared to the untreated check. Surprisingly, reduction in tunnel number by the best liquid insecticides was comparable to the best granular insecticides. Further trials are needed at the small plot and field level in southern Minnesota to determine if the trends observed in this single trial are representative. Hopefully, additional trials will be possible before ECB populations again reach outbreak levels and the insecticide performance data is needed for calculating economic thresholds.

Table 5. Granular and liquid insecticide effectiveness against first-generation ECB in southern Minnesota. David Miners farm, Beardsley, Big Stone Co., 1986.

| Insecticide | Rate (lb ai/acre) | Tunnels per 10 infested plants | % control |
|---|---|---|---|
| Granules | | | |
| PP 993 1.5G | 0.15 | 1.25a | 89.3 |
| Ambush 1.5G | 0.15 | 1.50a | 87.1 |
| Fortress 15G | 0.75 | 1.75ab | 85.0 |
| Dipel 10G | 1.00 | 3.00ab | 74.2 |
| Furadan 15G | 1.00 | 3.25ab | 72.1 |
| Lorsban 15G | 1.00 | 3.50ab | 69.9 |
| Dyfonate 20G | 1.00 | 3.50ab | 69.9 |
| Thimet 20G | 1.00 | 4.00ab | 65.6 |
| Diazinon 14G | 1.00 | 4.00ab | 63.5 |
| Dipel 14G | 1.00 | 5.75 b | 54.9 |
| Check | ---- | 11.63 c | ---- |
| Liquids | | | |
| Baythroid 2E | 0.025 | 1.00a | 90.8 |
| Penncap-M 2F | 1.00 | 2.00ab | 81.5 |
| Ambush 2E | 0.15 | 2.75ab | 74.6 |
| Lorsban 4E | 1.00 | 3.00abc | 72.3 |
| Pounce 3.2E | 0.15 | 4.00abcd | 63.1 |
| Penncap-M 2F | 0.50 | 4.63abcd | 57.2 |
| Dipel ES | * | 4.75abcd | 56.1 |
| Furadan 4F | 1.00 | 5.38 bcd | 50.3 |
| Sevin XLR Plus | 2.00 | 6.75 cd | 37.7 |
| Pydrin 2.4E | 0.15 | 7.50 de | 30.7 |
| Asana 1.9E | 0.025 | 7.63 de | 29.5 |
| Check | ---- | 10.75 e | ---- |

* Applied at 2 pts per acre.
Means followed by the same letter do not differ significantly ($p<0.05$, DMRT).

ACKNOWLEDGEMENTS

The research reported in this paper would not have been possible without the generous support of the people of Minnesota through the Minnesota Agricultural Experiment Station and the agrichemical companies whose products were evaluated in these trials. The following farmers unselfishly provided their fields for insecticide trials: The Bauers, David Miners, Don Christenson, Milo Carlson, Roland & David Lanctot, and the Northwest Experiment Station. Insecticides were applied by the following aerial applicators: Roger Olson & Jim Ashmore, Gasper Air Spray. The following people played key roles: Dan Barber - Dow, Dean Herzfeld and Carlyle Holen, MN Ext. Serv.

# INSECTS AND GRAIN STORAGE - CURRENT CONTROL RECOMMENDATIONS

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## INSECT MONITORING

A total of 65 farm storages containing corn, wheat or barley in the western counties of Minnesota were selected for inspection each month throughout the summer of 1986. The beetles were collected with perforated plastic pitfall traps and Indianmeal moth with pheromone traps. Two samples (1500-2000 g) of grain were removed from near the pitfall traps and isolated in air-tight plastic bags. These samples were then examined in the laboratory including the number and identification of insects sieved from the grain. The relative effectiveness of monitoring insect infestation was compared with the insect traps versus screening grain samples.

### Insects Via Grain Samples

An average of 44% of the corn, 96% of the wheat, and 83% of the barley samples were infested with one or more species of insects (Table 1). As expected, the incidence of the insects infesting grain based on grain samples was equal to or greater in August than in May and/or June.

The flat grain beetle, *Cryptolestes spp.* was the most abundant, and was present in 30% of the corn (Table 2), 77% of the wheat (Table 3), and 44% of the barley (Table 4). The species infesting corn were *Cryptolestes spp.*, foreign grain beetle, *Ahasverus advena*, red flour beetle, *Tribolium castaneum*, sawtoothed grain beetle, *Oryzaephilus surinamensis*, Indianmeal moth, *Plodia interpunctella*, American black flour beetle, *Tribolium audax*, hairy fungus beetle, *Typhaea stercorea*, and the larger flour beetle, *Cyaneus angustus* (Table 2). The species infesting wheat were *Cryptolestes spp.*, *A. advena*, *T. castaneum*, *O. surinamensis*, *T.audax*, *T. stercorea*, and the lesser grain borer, *Rhyzopertha dominica* (Table 3). Except for *P. interpunctella*, *T. audax*, and *C. angustus*, all other insects species that were present in corn were also present in barley (Table 4). However, in barley, we also observed infestations of the rice weevil, *Sitophilus oryzae*, longheaded flour beetle, *Latheticus oryzae*, and *R. dominica*.

*Plodia interpunctella* larvae were seldom noted in the grain samples, although adult males were captured in pheromone traps.

### Insect Via Traps

Infestations based on the number of insects captured in the pitfall traps indicated that 87, 100, and 100% of the corn, wheat, and barley storages, respectively, were infested with one or more species of insects (Table 5). The higher infestation value obtained with pitfall traps compared to insects sieved from grain samples was anticipated. The pitfall traps have a multi-species trapping capability and they can be left in the grain for long periods. In the current studies we also captured two to five additional species in pitfall traps in barley than in grain probe samples.

Based on trap catch, the incidence of Typhaea stercorea was highest (50%) in corn storages, while Cryptolestes spp. was the most commonly occurring species in both wheat (82%) and barley (94%) (Table 6). Fungivorous beetles such as Cryptolestes spp., A. advena, and T. stercorea occurred in more than 46% of all 3 types of grain.

Cyaneus angustus was reported in 1981 as a serious pest of stored corn in Minnesota. Our results with traps showed C. angustus to be infesting 40% of corn storages but only 18% of the wheat and 6% of the barley. Oryzaephiluis surinamensis was abundant in barley (50%) compared to wheat (27%) and corn (7%). Other insect species were found in relatively low numbers that differed depending on the type of grain.

## GRAIN STORAGE RECOMMENDATIONS

High grain temperatures and moistures, along with excessive grain dockage or broken kernels, interact providing the necessary conditions for stored-grain insect reproduction and survival. The most favorable grain temperature for these insects is about 80$^{o}$F. At temperatures above 90$^{o}$F or below 60$^{o}$F, reproduction is nill, developmental time is extended, and survival time is reduced.

The most favorable grain moisture range for stored-grain insects is 12% to 18%. Insects that feed on mold prefer the higher moisture levels. They also prefer grain with the highest dockage. This is the primary reason insects often accumulate in spout line areas.

Over-filling bins is a common practice in Minnesota. Unfortunately this results in inadequate space to inspect or treat the grain. Uneven grain surfaces also contribute to nonuniform air flow during aeration. Level the grain, after binning is complete, at least 6 inches below the top of the bin wall. Or, immediately following harvest, level the grain to the proper height by removing sufficient amounts from the spout line area. This grain will contain a relatively high percentage of broken kernels and foreign matter. Feed this grain livestock as soon as possible or screen and treat it before rebinning.

Inspect grain at 7 to 14 day intervals, depending on the potential for insect infestations. Grain with temperatures exceeding 50$^{o}$F should be checked every 7 days. Check for insects using insect traps, by screening them from the grain, examining kernels for damage, looking for webbing, detecting off-odors, or monitoring grain temperatures. The temperature could be as high as 110$^{o}$F just due to the insect activity. During the summer and fall, insect infestations are usually near the surface of the grain. During cold weather these insects will congretate to the center and lower portions of the grain mass and may escape detection until extensive heating and damage has developed.

## PREVENTING INFESTATION OF STORED-GRAIN INSECTS

### Spraying Facilities

Thoroughly clean combines, trucks, wagon beds, conveyors, elevators and bins. Spray the surface of the equipment that will be in contact with the grain with one of the following insecticides at least two weeks before harvest.

| Insecticides | Amount of insecticide mixed with water |
|---|---|
| chlorpyrifos-methyl 43.2% E* | 1/2 pt/6 1/2 gallons |
| methoxychlor 50% W.P. | 1 lb/2.5 gallons |
| methoxychlor 25% E.C. | 1 qt/2.5 gallons |
| malathion-premium grade 50 to 57% E.C. | 1 pt/3 gallons |

E.C. - emulsifiable concentrate
W.P. - wettable powder
E - emulsifiable concentrate
* - Not registered for equipment or bins receiving corn

Spray to the point of run-off using 1 gallon of total formulation per 500 square feet of surface when using malathion or methoxychlor or 1 gallon per 650 to 1250 square feet when using chlorpyrifos-methyl. Spray the outside walls of the bins to a height of 6 feet and the ground to a distance of 6 feet out from each bin's foundation. To insure uniform dosages, wettable powder suspensions must be agitated frequently in the sprayer during applications. Mix only one day's supply of these formulations as they may lose their effectiveness if in contact with water overnight.

It is not recommended that new grain be mixed with old grain in storage, However, if it is not possible to remove the old grain before harvest, check it carefully for stored-grain insects and, if needed, treat it with recommended residual insecticides or fumigants before adding new grain.

## GRAIN PROTECTANTS

Insect infestation is prevented or reduced by treating the grain with a residual insecticide as it is moved into storage. The current insecticide formulations registered are described below:

Chlorpyrifos-methyl (Reldan 4E) is a new residual insecticide for stored wheat, oats, rice, sorghum or barley. To date, it is not registered for use on corn. Reldan is effective 9 to 18 months against stored grain insects including those resistant to malathion. Chlorpyrifos-methyl (43.2%) should be diluted with water and applied to grain during transfer to storage. To obtain the recommended 6 ppm residues apply 11.5 fl. oz.

of concentrated chlorpyrifos-methyl to 1-5 gallon of water per 1,000 bu. for wheat, or 9.2 fl. oz. for barley and 6.2 fl. oz. for oats. Chlorpyrifos-methyl can also be applied as a 3% dust or as a liquid in food grain mineral oils. These are preferred formulations when low air temperatures may freeze water based mixtures.

Malathion is registered for direct use on stored corn, oats, rye, sorghum, wheat, and barley. The protection provided by malathion is reduced to a few weeks if the treated grain is warm and has a high moisture level. Malathion on cool dry grain should be effective for three to six months. The increasing resistance of stored grain insects to malathion (especially the Indianmeal moth) is also reducing its effectiveness. Malathion is formulated to be applied as a dust or liquid. Dusts can be added to the grain stream as it is elevated or conveyed into the bin.

malathion - 1 pint 50% to 57% premium-grade E.C. per 2 to 5 gallons water per 1,000 bushels of corn or small grain.
malathion - 1% premium-grade in wheat flour dust, 60 pounds per 1,000 bushels of corn or small grain (also available in 2, 4, and 6% dust formulations).

Pirimiphos-methyl (57%) (Actellic 5E) was recently registered as a grain protectant for corn and grain sorghum. It is effective against malathion resistant insects and is expected to last 9 to 18 months depending on the moisture and temperature of the grain. Mix 12 fl. oz. of pirimiphos-methyl (57%) with water to obtain the desired rate in 5 gallons of formulation/1,000 bu.

## GRAIN FUMIGANTS

Grain should not require fumigation during the first year of storage in Minnesota, especially if sanitation, aeration and residual insecticide recommendations are used properly (see Preventing Stored Grain Insect Infestation, AG-FS-0997). Fumigation, however, may be justified if the insect prevention efforts fail.

Fumigants are formulated as solids, liquids, or gases but they all must be in the gaseous state to penetrate grain and kill the insects. None of the fumigants have long-term effectiveness. Most will leak out of the bins within a few days. The rate of fumigant loss depends primarily on the fumigant, dosage, the temperature and moisture of the grain being fumigated, and the tightness of the bin.

It is safer and usually more effective to have your stored grain fumigated by a licensed and certified professional fumigator than to do it yourself. There are several reasons to consider hiring a professional to conduct your fumigations. The most important is your personal risk in handling a highly toxic pesticide. A professional fumigator will 1) have fumigating knowledge and experience, 2) have the special equipment required to apply fumigants, and 3) be aware of the safety devices such as respiration protection and gas concentration monitoring equipment. In fact, EPA's Label Improvement Program, should eliminate fumigation by everyone except professional fumigators because of increased safety requirements when fumigating.

The grain fumigant application method most often used on Minnesota farms for many years has involved pouring liquid-type fumigants onto the surface of the grain mass. Most of these liquid-type fumigants are composed primarily of 80% carbon tetrachloride and 20% carbon disulfide. However, as of June 30, 1986 all these "80:20" formulations were banned by the Environmental Protection Agency and any future use on stored grain is illegal. Consequently there are no longer any "general use" stored grain fumigants available. The restricted use fumigants that are still available are identified as follows:

Bro-Mean C-2R
Brom-O-Gas
Degesch Fumi-Cel Plates
Degesch Fumi-Strip
Degesch Magtoxin Pellets
Degesch Magtoxin Pellets - Prepac
Degesch Magtoxin Tablets
Degesch Phostoxin Coated Pellets
Degesch Phostoxin Coated Pellets - Prepac
Degesch Phostoxin New Coated Tablets
Degesch Phostoxin Prepac Rope
Detia Gas Ex-B
Detia Pellets
Detia Tablets
Fumitoxin Aluminum Phosphide Bags
Fumitoxin Coated Pellets
Fumitoxin New Coated Tablets
Gastoxin Fumigation Pellets
Gastoxin Fumigation Tablets
L Fume
Methyl Fume
Meth-O-Gas
Quick Phos Pellets
SMCP Chloropicrin
Soweco Brand Chloropicrin 100
Terr-O-Gas 98

Although the above fumigants are labeled for use on stored grain, they may or may not be registered for use in all grains or in empty storage structures. Please read the label for such details. The label is a legal document and its directions must be followed.

Table 1. Number of corn, wheat, and barley storages infested in Minnesota during May June, and August 1986.

| Grain type | No. of storages sampled | | | No. of storages infested | | | Infested storages Percent | | | Infested storages Avg. ± SE (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | May | June | Aug. | May | June | Aug. | May | June | Aug. | |
| Corn | 30 | 29 | 29 | 4 | 11 | 23 | 13.3 | 37.9 | 79.3 | 43.5 ± 19.3 |
| Wheat | 15 | 11 | 8 | 13 | 11 | 8 | 86.7 | 100 | 100 | 95.6 ± 4.4 |
| Barley | 20 | 12 | 11 | 15 | 10 | 10 | 75.0 | 83.3 | 90.9 | 83.1 ± 4.6 |

Table 2. Occurrence of insect species in samples of farm stored corn in Minnesota during May, June, and August, 1986.

| Insect species | % Infested May[a/] % | % Infested June[b/] % | % Infested August[c/] % | Avg ± SE |
|---|---|---|---|---|
| *Cryptolestes spp.* | 10.0 | 24.1 | 55.2 | 29.8 ± 13.4 |
| *A. advena* | 0.0 | 3.4 | 55.2 | 19.5 ± 17.9 |
| *T. stercorea* | 0.0 | 17.2 | 34.5 | 17.2 ± 10.0 |
| *C. angustus* | 0.0 | 3.4 | 20.7 | 8.0 ± 6.4 |
| *O. surinamensis* | 3.3 | 0.0 | 17.2 | 6.8 ± 5.3 |
| *P. interpunctella* | 3.3 | 3.4 | 6.9 | 4.5 ± 1.2 |
| *T. castaneum* | 0.0 | 0.0 | 6.9 | 2.3 ± 2.3 |
| *T. audax* | 0.0 | 0.0 | 6.9 | 2.3 ± 2.3 |

a/ 30 storages sampled.
b/ 29 storages sampled.
c/ 29 storages sampled.

Table 3. Occurrence of insect species in samples of farm stored wheat in Minnesota during May, June, and August, 1986.

| Insect species | % Infested | | | |
|---|---|---|---|---|
| | May[a/] | June[b/] | August[c/] | Avg ± SE |
| *Cryptolestes* spp. | 53.3 | 90.9 | 87.5 | 77.2 ± 12.0 |
| *A. advena* | 26.7 | 63.6 | 100.0 | 63.4 ± 21.2 |
| *O. surinamensis* | 26.7 | 54.5 | 62.5 | 47.9 ± 10.8 |
| *T. stercorea* | 6.7 | 18.2 | 87.5 | 37.5 ± 25.2 |
| *T. castaneum* | 20.0 | 18.2 | 25.0 | 21.1 ± 2.0 |
| *R. dominica* | 6.7 | 0.0 | 37.5 | 14.7 ± 11.5 |
| *T. audax* | 6.7 | 9.1 | 12.5 | 10.8 ± 8.9 |

a/ 15 storages sampled.
b/ 11 storages sampled.
c/ 8 storages sampled.

Table 4. Occurrence of insect species in samples of farm stored barley in Minnesota during May, June, and August, 1986.

| Insect species | % Infested | | | |
|---|---|---|---|---|
| | May[a/] | June[b/] | August[c/] | Avg ± SE |
| *T. castaneum* | 41.0 | 58.3 | 54.5 | 51.3 ± 5.2 |
| *O. surinamensis* | 50.0 | 41.7 | 45.5 | 45.7 ± 2.4 |
| *Cryptolestes* spp. | 35.0 | 41.7 | 54.5 | 43.7 ± 5.7 |
| *R. dominica* | 11.8 | 25.0 | 81.8 | 39.5 ± 21.5 |
| *A. advena* | 15.0 | 33.3 | 27.3 | 25.2 ± 5.4 |
| *S. oryzae* | 23.5 | 25.0 | 18.2 | 22.2 ± 2.1 |
| *T. stercorea* | 5.9 | 16.7 | 18.2 | 13.6 ± 3.9 |
| *S. granarius* | 0.0 | 8.3 | 9.1 | 5.8 ± 2.9 |
| *L. oryzae* | 0.0 | 8.3 | 0.0 | 2.8 ± 2.8 |

a/ 20 storages sampled.
b/ 12 storages sampled.
c/ 11 storages sampled.

Table 5. Insect infestation during 1986 in corn, wheat, and barley storages in Minnesota sampled with pitfall plastic traps.

| Grain type | Number of storages | |
|---|---|---|
| | Sampled | Infested |
| Corn[a/] | 30 | 26 (86.7%) |
| Wheat[a/] | 10 | 10 (100.0%) |
| Barley[c/] | 16 | 16 (100.0%) |

a/ Traps placed in May and sampled in June.
b/ Traps placed in May-June and sampled in July.

Table 6. Occurrence of insect species in 1986 infesting farm stored corn, wheat, and barley in Minnesota using pitfall traps.

| Insect | % Infested | | |
|---|---|---|---|
| | Corn[a/] | Wheat[b/] | Barley[c/] |
| Cryptolestes spp. | 46.7 | 81.8 | 93.8 |
| A. advena | 46.7 | 54.5 | 62.5 |
| T. castaneum | 20.0 | 27.3 | 50.0 |
| T. stercorea | 50.0 | 45.3 | 37.5 |
| L. oryzae | 0.0 | 9.1 | 0.0 |
| S. oryzae | 3.3 | 0.0 | 6.3 |
| Tenebrio molitor | 3.3 | 0.0 | 6.3 |
| O. surinamensis | 6.7 | 27.3 | 50.0 |
| R. dominica | 0.0 | 18.2 | 12.5 |
| C. angustus | 40.0 | 18.2 | 6.3 |
| P. interpunctella[d/] | (25/30) | (6/11) | (14/16) |

a/ 30 storages sampled.
b/ 11 storages sampled.
c/ 15 storages sampled.
d/ P. interpunctella counts were based on adult males in pheromone traps placed above grain. Numbers in parenthesis represent the proportion of storages with adults present. No larval stages were found in pitfall traps.

RECOMMENDATIONS FOR 1986

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Chemical damage to the crop

Suspected pesticide damage and/or pesticide misuse should be reported, as soon as it is well defined, to the MDA St. Paul office or your local Agronomy District Coordinators. County agents can usually provide the name of and how to reach the appropriate contact person. Growers can only benefit from early reporting, as diagnosis can be more thorough. Such documentation aids in subsequent damage claims.

Honey bee protection

Carbaryl (Sevin), ULV malathion, methidathion (Supracide), methyl parathion (Penncap M), and parathion, for example, are very toxic to bees. Crops in bloom should not be treated and applications should not be made near bee yards or when bees are present in fields to be treated. Do not move bees into alfalfa fields treated with Furadan 4F within 7 days of treatment. A listing of insecticides and their toxicity to honey bees is contained in Entomology AG-FS-1028, Protecting Honey Bees from Insecticides and in AG-BU-0499, Insecticides.

Insecticide movement in soil

Insecticides applied to steep slopes often move with soil and water in the erosion process. Greatest movement occurs where slope is greatest and erosion control (eg. tillage, contouring, and terracing) is least. The magnitude of movement will be related to amount of run-off and the concentration of the insecticide in the soil. Early season run-off shortly after application, for example, will move the greatest amounts of pesticides.

In the Karst area in southeastern Minnesota the same factors that contribute to soil-pesticide run-off may also potentially contribute to movement of pesticide into aquifers.

A third situation exists where pesticides have potential to move into shallow aquifers. In this case pesticide solubility and the volume of water moving past the root zone are major variables in moving pesticides to the water table. Areas of Minnesota where greatest potential for this to take place are the glacial outwash sand plains in the central part of the state. Care should be taken to use as little pesticide as is practical and perhaps to be concerned about both pesticide solubility and amounts of water added to these soils.

Handling of highly toxic insecticides

Aldicarb (Temik), demeton (Syston), disulfoton (DiSyston), mevinphos (Phosdrin), methomyl (Lannate, Nudrin), methyl parathion, parathion, phorate (Thimet), and phosphamidon (Dimecron) are highly toxic chemicals.

They should be handled only by persons knowledgeable in their safe use. Posting of fields in which these chemicals are foliarly applied is advisable. WHEN THE LABEL SAYS "POST TREATED AREAS", POSTING IS A LEGAL REQUIREMENT. Protective measures outlined on the label, including clothing, method of application and re-entry period, should be followed carefully. Granular formulations are less hazardous during application than are liquids. However, in all cases avoid inhaling dusts or vapors, avoid skin contact with the chemical, and change clothing and shower thoroughly after applying insecticides.

Insect and Insecticide management to reduce resistance potential

Insect resistance develops in insect populations as a result of intense selection (near 100% kill) by the insecticide. Selective pressure is increased when dosage is increased, spray frequency is increased and more life stages of the insect are exposed to the insecticide. Immigration of insecticide susceptible insects into treated populations is the major factor preventing the build-up of resistance.

The question of how to manage pest insect populations in such a manner that initially effective insecticides remain effective for a longer period suggests the possibility of two patterns of insecticide use. Both patterns have been subjected to tests through modeling a theoretical insect population with various assumed constraints.

The first strategy can be called the "high dose" strategy. This is, in simple terms, the use of an insecticide at a level that "eliminates" a resident pest population (i.e. 100% control). In addition, the insecticide is assumed to have no persistence so that immigrants are not subjected to any selective pressure, and there is no outward migration of treated (i.e. resistant) individuals. Finally, it is assumed the insecticide dosage does not lead to collateral resistance in other pest species in the target area.

Authors who have spent considerable thought on these problems have the general consensus that it is not likely all, or very many, of the assumptions upon which the "high dose" strategy is based are valid in nature. And, if they are, they are not likely to continue once chemical selective pressure is placed on a population. Thus, at best, a high dose strategy could only be used very early in an insecticide history.

The second of these strategies has been termed the "low dose" strategy. It is assumed low dosage treatments remove susceptible insects only. High immigration of susceptible insects into the area treated is again assumed. Insecticide is used at the least dosage which provides maximum economic benefit.

Because most workers feel the assumptions upon which the "low dose" strategy are based are most likely to be operative in nature we feel it prudent to encourage its use. It is basically the use of an insecticide only when net profit can be realized by the grower from the use of the insecticide. Furthermore, the insecticide dosage should not be higher than is necessary for the greatest net return to chemical dollar. Professionally speaking, this means insecticide use should be based on field monitoring and the obtaining of precise pest counts.

## INSECTICIDE SUGGESTIONS TO CONTROL INSECT PESTS OF FIELD CROPS IN 1987

Abbreviations used in tables: phi - pre harvest interval, EC or E - emulsifiable concentrate, D - dust, F - flowable, G - granules, S - solution, WP - wettable powder, and SP - soluble powder. Dosages of insecticides are actual chemical per acre, with some exceptions.

### ALFALFA

| Insect | Insecticide | Formulation Recomm. | Formulation Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Alfalfa weevil | azinphosmethyl (Guthion) | 50% WP only | 1 - 1 1/2 lb | 1/2-3/4 lb | 21 day phi, not more than one application per cutting. |
| | carbaryl (Sevin) | XLR plus | 2 - 3 pt | 1-1 1/2 lb | 3 day phi. Note plant damage precautions on label. May favor aphid buildup. |
| | *carbofuran (Furadan) | 4F | 1/2 - 1 pt | 1/4-1/2 lb | 7 day phi 1/4 lb, 14 days 1/2 lb. Not more than 2 application per season, or 1 per cutting. Note rotation restrictions on label. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 14 day phi. Not more than 1 application per cutting. |
| | malathion (Cythion) | 5E | 2 pt | 1 1/4 lbs | No time limitations. |
| | malathion plus methoxychlor | 2E+2E | 3 pt | 3/4 lb+3/4 lb | 7 day phi. Available as a ready-to-use mixture. |
| | *methidathion (Supracide) | 2E | 2 pt | 1/2 lb | 10 day phi. |
| | *methyl parathion (Penncap-M) | 2E | 1 pt | 1/4 lb | 15 day phi. |
| | phosmet (Imidan) | 50 WP | 2 lb | 1 lb | 7 day phi. Not more than one application per cutting. |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

Cut first crop early to avoid most losses. Treat when more than 30 percent of plant tips show feeding. Treat stubble if there are more than 8 larvae per square foot or when regrowth has 50 percent of the terminals with feeding or if larvae are delaying regrowth. Do not treat alfalfa in bloom.

---

| | | | | | |
|---|---|---|---|---|---|
| Aphids | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 14 day phi. Not more than 1 application per cutting. |
| | diazinon | 4E | 1 pt | 1/2 lb | 7 day phi. |
| | dimethoate (Cygon, Defend, Rebelate, Dimex 267) | 4E<br>2.67E | 1/2-1 pt<br>3/4-1 1/2 pt | 1/4-1/2 lb | 10 day phi, one application per cutting. |
| | malathion (Cythion) | 5E | 1 3/5 pt | 1 lb | No time limitations. |
| | *methyl parathion (Penncap-M) | 2F | 2 pts | 1/2 lb | 15 day phi. |
| | *parathion | 4E | 1/2 pt | 1/4 lb | 15 day phi. |

Control pea aphids if populations 2 weeks prior to harvest exceed an average of 1.2 per stem and plants are under drought stress. Spotted alfalfa aphids may severely damage new seedings.

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| | | | | | |
|---|---|---|---|---|---|
| Armyworms, cutworms | carbaryl (Sevin) | XLR plus | 3 pts | 1 1/2 lb | 3 day phi. Note plant damage precautions on label. May favor aphid buildup. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 14 day phi. Not more than 1 application per cutting. |
| | malathion (Cythion) | 5E | 2 pts | 1 1/4 lb | No time limitations. |
| | *methomyl (Lannate, Nudrin) | 90% SP<br>1.8E | 3/8 lbs<br>1 - 2 pts | 1/4-1/2 lb | 7 days till feeding or grazing; no time limit for harvest. Note plant damage precaution on label. |
| | *methyl parathion (Penncap-M) | 2F | 2 pts | 1/2 lb | 15 day phi. |
| | trichlorfon (Dylox, | 80 SP | 1 1/4 lb | 1 lb | No time limitations. Not more than |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | Proxol) | | | | 3 applications per cutting. May favor aphid buildup. |
| | Treat when more than 5 per square foot. | | | | |
| Leafhoppers | azinphosmethyl (Guthion) | 50% WP only | 1/2 - 1 lb | 1/4-1/2 lb | 16 day phi. Not more than one application per cutting. |
| | carbaryl (Sevin) | XLR plus | 2 pts | 1 lb | 3 day phi. Note plant damage precautions on label. May favor aphid buildup. |
| | *carbofuran (Furadan) | 4F | 1/2 - 1 pt | 1/4-1/2 lb | 7 day phi 1/4 lb; 14 days 1/2 lb. Not more than 2 applications per season, nor 1 per cutting. Note rotation restrictions on label. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 14 day phi. Not more than 1 application per cutting. |
| | diazinon | 4E | 1 pt | 1/2 lb | 7 day phi. |
| | dimethoate (Cygon, etc) | 4E | 1/2 - 1 pt | 1/4-1/2 lb | 10 day phi, the application per cutting. |
| | *methidathion (Supracide) | 2E | 2 pts | 1/2 lb | 10 day phi. |
| | methoxychlor (Methoxchlor, Marlate Prentox) | 2E | 4 pts | 1 lb | 7 day phi. |
| | phosmet (Imidan) | 50WP | 2 lbs | 1 lb | 7 day phi, one application per cutting. |
| | Apply when potato leafhoppers average or exceed 0.3 per pendulum sweep on alfalfa less than 3" tall, 0.4 per sweep on alfalfa 3-5" tall, 0.5 per sweep for 6-7" alfalfa, 1.0 per sweep for 8-11" alfalfa, and 2 per sweep on alfalfa 12" or taller. New seedings are most susceptible to injury. | | | | |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| Grasshoppers | azinphosmethyl (Guthion) | 50% WP only | 1 - 1 1/2 lb | 1/2-3/4 lb | 21 day phi. Not more than 1 application per cutting. |
| | carbaryl (Sevin) | XLR plus | 2 - 3 pts | 1-1 1/2 lb | 3 day phi. Note plant damage precautions on label. May favor aphid buildup. |
| | *carbofuran (Furadan) | 4F | 1/4 - 1/2 pt | 1/8 - 1/4 lb | 7 day phi, one application per season. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 14 day phi. Not more than 1 application per cutting. |
| | diazinon | 4E | 1 pt | 1/2 lb | 7 day phi |
| | dimethoate (Cygon, Rebelate) | 4E<br>2.67E | 1/2 - 1 pt<br>3/4 - 1 1/2 pt | 1/4-1/2 lb | 10 day phi, one application per cutting. |
| | malathion (Cythion) | 5E | 2 pts | 1 1/4 lbs | No time limitations. |

Control when there are more than 8 grasshoppers per square yard in the field, or treat margins after cutting at more than 20 per square yard.

| | | | | | |
|---|---|---|---|---|---|
| Spittlebug | chlorpyrifos (Lorsban) | 4E | 1 - 2 pts | 1/2-1 lb | 14 day phi 1/2 lb; 21 day phi 1 lb. Not more than 1 application per cutting. |
| | malathion (Cythion) | 5E | 1 3/5 - 2 pts | 1-1 1/4 lbs | No time limitations. |
| | methoxychlor (Methoxychlor, Marlate, Prentox) | 2E | 4 pts | 1 lb | 7 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 1 - 3 pts | 1/4-3/4 lb | 15 day phi. |

Apply on first crop when spittle masses average more than one per stem.

| | | | | | |
|---|---|---|---|---|---|
| Plant bugs | dimethoate (Cygon, Rebalate) | 4E<br>2.67E | 1/2 - 1 pt<br>3/4-1 1/2 pt | 1/4 - 1/2 lb | 10 day phi, one application per cutting. |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| Insect | Insecticide | Recomm. | Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| | malathion + methoxychlor | 2E + 2E | 3 pts | 3/4 lb + 3/4 lb | 7 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 2 - 3 pts | 1/2-3/4 lb | 15 day phi. |
| | trichlorfon (Dylox) | 80 SP | 20 oz | 1 lb | No time limitations. Not more than 3 applications per cutting. May favor aphid buildup. |

Control seldom needed except on seed crop. Cut early to avoid injury.

## ALFALFA, CLOVER
(FOR SEED ONLY)

| Insect | Insecticide | Formulation Recomm. | Formulation Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Plant bugs | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 14 day phi. Not more than 1 application per cutting. |
| | endosulfan (Thiodan) | 3E | 3 pts | 1 lb | Do not harvest for forage or graze. |
| | trichlorfon (Dylox) | 80SP | 20-30 oz | 1-1 1/2 lbs | 7 day phi. Chaff may be used for feed or forage, but do not cut green crop for these purposes. |

Do not treat crop in bloom.

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

## CORN, FIELD

| Insect | Insecticide | Formulation Recomm. | Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| | | | | (per 1000 row ft.) | |
| Corn rootworm larvae | *carbofuran (Furadan) | 15G | 8 oz | 1.2 oz = 1 lb/acre in 40" rows | May be applied in furrow or banded. |
| | chlorpyrifos (Lorsban) | 15G | 8 oz | | Apply as band in front of press wheel. |
| | *ethoprop (Mocap) | 15G | 8 oz | | Phytotoxic - Do not apply in-furrow or band over open seed furrow. |
| | *fonofos (Dyfonate) | 20G | 6 oz | All same as above | Phytotoxic-Do not apply in-furrow. |
| | *phorate (Thimet) | 20G | 6 oz | | Phytotoxic-Do not apply in-furrow. |
| | *terbufos (Counter) | 15G | 8 oz | | May be applied in-furrow or in band. |
| | trimethacarb (Broot) | 15G | 8 oz | | Phytotoxic-Do not apply in-furrow or band over open seed furrow. |

The potential for rootworm infestation can be predicted by scouting corn fields weekly for adult beetles during August. If adult counts average less than one beetle per plant during August, a soil insecticide used the next spring will rarely increase yield. If adult counts average more than 5 beetles per plant, rotate to a crop other than corn. Rootworm control may be unsatisfactory during heavy rootworm infestation. If a field was not scouted last year, use a soil insecticide where corn follows corn.

Soil insecticides may be applied during cultivation. Cultivator application of Broot, Counter, Dyfonate, Furadan (15G, 4F), Lorsban (15G, 4E), Mocap, or Thimet/Phorate may provide effective control if applied before larvae hatch in mid-June. Apply at base of stalks and cover with soil. This method may provide poor control if dry soil conditions prevent effective insecticide movement into the root zone.

Avoid continuous use of the same soil insecticide. Continuous use may condition the soil to rapidly degrade the insecticide and result in unsatisfactory control. Rotate insecticides, especially if poor performance occurs.

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

Treatment of first-year corn for corn rootworms is only recommended if that field or adjacent first-year fields have suffered corn rootworm damage in previous years.

| | | | | | |
|---|---|---|---|---|---|
| | | | (per 1000 row ft.) | | |
| Wireworms | *carbofuran (Furadan) | 15G | 8 oz | 8 oz | Apply in-furrow. |
| | chlorpyrifos (Lorsban) | 15G | 16 oz | 2.4 oz | Band or in-furrow at planting. |
| | | | 13.4 lbs/acre | 2 lbs/acre | Broadcast ppi. |
| | *ethoprop (Mocap) | 15G | 8 oz | 1.2 oz | Apply in 7" band only. |
| | *terbufos (Counter) | 15G | 8 oz | 1.2 oz | Band or in-furrow at planting. |
| | *phorate (Thimet) | 20G | 6 oz | 1.2 oz | Apply in 7" band only. |

In fields with a history of wireworm damage, bait stations can be used to sample wireworms 2-3 weeks before planting. Treatment is recommended if captures average more than 1 per trap. Seed treatments containing lindane will protect the germinating seed in light to moderate infestations but will not protect the emerged plant.

| | | | | | |
|---|---|---|---|---|---|
| | | | (per 1000 row ft.) | | |
| White grubs | chlorpyrifos (Lorsban) | 15G | 8-16 oz | 1.2-2.4 oz | Apply in-furrow. |
| | | 4E | 4 pts/acre | 2 lbs/acre | Broadcast and incorporate before planting. |
| | *phorate (Thimet) | 20G | 6 oz | 1.2 oz | Apply in 7" band. Do not place in contact w/seed. |
| | *terbufos (Counter) | 15G | 8 oz | 1.2 oz | Apply in 7" band or in-furrow. |
| Seed-corn maggot, seed-corn beetle | chlorpyrifos (Lorsban) | 50 SL | 2 oz/100 lb | 1 oz/100 lb | Seed treatment only. Will not control wireworms. |
| | diazinon | | See Label | 1-1 1/2 oz per bu. | Use slurry treatment with cyclo-planters. Will not control wireworms. |
| | lindane | | See Label | 1 oz per bu. | Has some wireworm activity. |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

Seed treatments are strongly recommended for fields where manure or cover crops were partially buried by recent tillage. Planting time applications of some corn rootworm insecticides (Counter, Dyfonate, Furadan, Lorsban and Thimet) will also control these insects.

| | | | | | |
|---|---|---|---|---|---|
| Stalk Borer | chlorpyrifos (Lorsban) | 4E | 2 - 3 pt | 1.0-1.5 | Apply 11 days after application of glyphosate (Roundup) or 3-5 days after paraquat. DO NOT tank-mix with herbicides. 35 days phi forage or silage. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3-10 2/3 fl oz | .1 - .2 | Note tank mix limitations. 21 day phi. |
| | *permethrin (Ambush, Pounce) | 2E<br>3.2E | 6.4-12.8 fl oz<br>4-8 fl oz | 0.1-0.2<br>0.1-0.2 | Note tank mix limitations. Apply before brown silks appear. |

Apply insecticides before stalk borer movement from grassy hosts to corn for effective control. Burndown herbicides can be used to initiate movement. Apply alone or, where permitted, tank mix with appropriate herbicides. Insecticide treatment only reduces, not eliminates, stand loss. Long term elimination of in-field trouble spots requires control of perennial grassy weeds (e.g., quack grass). Corn rootworm insecticides, applied at planting, will not prevent stand loss.



| | | | | | |
|---|---|---|---|---|---|
| Hop Vine Borer | None Labelled | | | | |

Where repeated infestations occur along field margins, fence rows or waterways, apply fenvalerate (Pydrin), permethrin (Ambush, Pounce) or flucythrinate (Payoff) when stand loss is first noticed. Within fields, spot treat grassy trouble spots at planting and repeat two weeks later. Long term elimination of infield trouble spots depends on control of perennial grassy weeds (e.g. quack grass, woolly cupgrass) and crop rotation.

| | | | | | |
|---|---|---|---|---|---|
| Cutworms | carbaryl (Sevin) | 5% Bait<br>20% Bait | 20-40 lbs<br>10-20 lbs | 1 - 2 lb<br>1 - 2 lb | No time limitations. Bait is more effective than sprays for cutworms except under dry |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | | | | | conditions. |
| | chlorpyrifos (Lorsban) | 4E | 2 - 3 pt | 1 - 1 1/2 lb | 35 days forage or silage |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 21 day phi. |
| | *flucythrinate (Payoff) | 2.5E | 2-4 fl oz | 0.04-0.08 lb | 60 day phi. |
| | *permethrin (Pounce, Ambush) | 3.2E<br>2E | 4 fl oz<br>6.4 fl oz | 0.1 lb | Apply before brown silk. Effective as rescue or planting time sprays. |

Apply when 3% to 6% of the plants are cut and small larvae (<3/4") are present.
NOTE: Lorsban 15G, Dyfonate 20G, Counter 15G, Furadan 15G and Mocap 15G are also registered for cutworm control or suppression. With these "at-planting" treatments, additional treatment may be required under moderate to heavy infestations. "Rescue" sprays provide more consistent and cost-effective control than do granules applied at planting. Surface treatments are usually ineffective against subterranean species (e.g. glassy cutworm).

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| | | | | | |
|---|---|---|---|---|---|
| Armyworm | carbaryl (Sevin) | All e.g. XLR | 3-4 pts | 1 1/2 - 2 lb | No time limitations. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 35 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 1/10 lb | 21 day phi. |
| | *methomyl (Lannate, Nudrin) | All e.g. 90% SP | 4.5-9oz | 1/4 - 1/2 lb | 3 day phi, forage. |
| | *methyl parathion (Penncap-M) | 2F | 2 pts | 1/2 lb | 12 day phi. |
| | *parathion | 8E | 1/4 - 3/8 pt | 1/4 - 3/8 lb | 12 day phi. |
| | *permethrin (Pounce, Ambush) | 3.2E<br>2E | 4 fl oz<br>6.4 fl oz | 1/10 lb | 12 day phi. |
| | trichlorfon (Dylox) | 80% SP | 1 1/4 lb | 1 lb | No time limitations. |

Treat when more than 25% of the plants are infested with 2 or more larvae or more than 70% of the plants have 1 or more larvae. Higher rates are for large armyworms. Apply in evening for best control.

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* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| European corn borer (First & second brood) | *Bacillus thuringiensis* (Dipel) | 10G | 10 lb | 1 lb | No time limitations. |
| | | ES | 1.5 - 2 pts | --- | No time limitations. Center pivot or ground application only. |
| | carbaryl (Sevin) | All e.g. XLR | 2-4 pts | 1 - 2 lb | No time limitations. |
| | *carbofuran (Furadan) | 15G<br>4F | 6.7 lb<br>2 pts | 1 lb | 30 day phi forage or grain. No more than 2 foliar applications. |
| | chlorpyrifos (Lorsban) | 15G<br>4E | 6.7 lb<br>2 pts | 1 lb | 35 day grain, 14 days forage. Does not perform well with low gallonage. |
| | diazinon | 14G | 7.1 lb | 1 lb | No time limitations grain, 10 day phi forage. |
| | *fonofos (Dyfonate) | 20G | 5 lb | 1 lb | 30 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 1 - 2 pt | 1/4-1/2 lb | 12 day phi. Do not apply when foraging honeybees are present. |
| | *permethrin (Pounce, Ambush) | 3.2E<br>2E<br>1.5G | 1/4 - 1/2 pt<br>6.4-12.8 fl oz<br>6.7 - 13.4 lbs | .1 - .2 lb | Spray or granules. Do not apply after brown silk stage. |
| | *phorate (Thimet) | 20G | 5 lb | 1 lb | First generation only, 1 application, 30 day phi. |

FIRST GENERATION: Treat when 50% of the plants are infested with fresh egg masses or show shotholing of whorl leaves. Thresholds may be lower for high-value seed fields (25%) or fields of exceptional yield potential (35%). Dissect several whorls to insure larvae are present and accessible to insecticides. Direct first-generation corn borer treatment into the whorl. Granules usually perform better than sprays.
SECOND GENERATION: Treat when 50% of the plants are infested with fresh egg masses or newly hatched larvae. Sprays should be applied with sufficient water to insure thorough coverage in the ear zone. Repeat applications may be required. If fields are heavily infested, harvest early.
CENTER PIVOT APPLICATION: Dipel ES, Sevin 80S, Lorsban 4E, Penncap-M 2F, and Pounce 3.2E are labelled for center pivot application. Make sure your system is properly equipped and calibrated. Follow label directions.

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NOTE: Carbofuran (Furadan), fonofos (Dyfonate), or phorate (Thimet) should not be used in seed production fields to be detasseled by hand.

| | | | | | |
|---|---|---|---|---|---|
| Aphids | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 35 days to feeding. |
| | diazinon | 50% WP | 2 lb | 1 lb | No time limitations. |
| | | 4E | 2 pts | | |
| | *disulfoton (DiSyston) | 8E | 1/2 pt | 1/2 lb | 28 day phi. |
| | malathion (Cythion) | 5E | 1 1/2 pt | 1 lb | 5 day phi. |
| | *methomyl (Lannate) | All e.g. 90% SP | 4 oz | 1/4 lb | 3 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 1 pt | 1/4 lb | 12 day phi. Aerial application only. |
| | *parathion | 8E | 1/4 pt | 1/4 lb | 12 day phi. |

Chemical control of corn leaf aphids is seldom economically justified. If 10% of the plants have more than 500 aphids per plant prior to tasseling during drought stress, treatment may pay. Apply at tassel emergence.

| | | | | | |
|---|---|---|---|---|---|
| Corn rootworm adults | carbaryl (Sevin) | All e.g. XLR | 2 pts | 1 lb | No time limitations. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 35 day phi. |
| | diazinon | 50% WP | 2 lbs | 1 lb | No time limitations. |
| | | 4E | 2 pts | | |
| | *fenvalerate (Pydrin) | 2.4E | 1/3 - 2/3 pt | .1 - .2 | 21 day phi. |
| | malathion (Cythion) | 5E | 1 1/2 pt | 1 lb | 5 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 1 - 2 pt | 1/4 - 1/2 lb | 12 day phi. Do not apply when foraging honeybees are present. |
| | *permethrin (Pounce | 3.2E | 4-8 fl oz | 0.1 - .2 lb | Apply before brown silk. |
| | Ambush) | 2E | 6.4-12.8 fl oz | | |
| | phosmet (Imidan) | 50% WP | 1/2 - 1 lb | 1/4 - 1/2 lb | 14 day phi. |

Treat when beetles clip silks so as to prevent proper pollination. This usually occurs with

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

populations of 10 or more beetles per plant on corn which has less than 50% silk emergence. Seed fields may benefit from treatment at lower levels of beetle infestation.

| | | | | | |
|---|---|---|---|---|---|
| Grasshoppers | carbaryl (Sevin) | All e.g. XLR | 2-3 pts | 1-1 1/2 lb | No time limitations. |
| | chlorpyrifos (Lorsban) | 4E | 12-16 fl oz | 1/3 - 1/2 lb | No more than 3 parts per season. |
| | *carbofuran (Furadan) | 4F | 4-8 fl oz | 1/8 - 1/4 lb | 30 day phi. |
| | diazinon | 4E | 2 pt | 1/2 lb | No time limitations. |
| | dimethoate (Cygon) | 4E | 1 pt | 1/2 lb | 14 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 1/10 lb | No time limitations. |
| | malathion (Cythion) | 5E | 1 1/2 pt | 1 lb | 5 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 2 pt | 1/2 lb | 12 day phi. |

Treat field margins early when grasshoppers are small and exceed 20 per sq. yd. in field margins or 8 per sq. yd. in field.

## **CORN, SWEET** (for processing) NOTE: See precaution on bees, p. __.



| Insect | Insecticide | Formulation Recomm. | Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Corn rootworm | chlorpyrifos (Lorsban) | | | | |
| | *ethoprop (Mocap) | | | | |
| | *fonofos (Dyfonate) | | | See field corn. | |
| | *phorate (Thimet) | | | | |
| | *terbufos (Counter) | | | | |
| | trimethacarb (Broot) | | | | |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| Seed corn maggot | diazinon | | See label | 1/4 oz/bu | Seed treatment-planter box mix. |
| | chlorpyrifos (Lorsban) | 50 SL | 2oz/100lb | 1 oz/100 lb | Slurry seed treatment. |
| Cutworms | carbaryl (Sevin) | 5 or 20% B | 20 or 5 lb | 1 lb | No time limitations. |
| | chlorpyrifos (Lorsban) | 4E | 2 - 3 pts | 1 - 1 1/2 lb | 35 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 1 day phi. |
| | *permethrin (Pounce, Ambush) | 3.2E 2E | 4 fl oz 6.4 fl oz | 0.1 lb | 1 day phi. |
| | trichlorfon (Dylox) | 80SP | 1 1/4 lb | 1 lb | No time limitations. Not more than 3 applications/season. |
| Armyworm | carbaryl (Sevin) | All e.g. XLR plus | 3-4 pts | 1 1/2 - 2 lb | No time limitations. Not Sevin 4-oil. |
| | chlorpyrifos (Lorsban) | 4E | 1-2 pt | 1/2-1 lb | 35 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 1 day phi. Do not exceed 2 lbs ai/A per season. |
| | methomyl (Lannate, Nudrin) | 90% SP | 1/4-1/2 lb | 4-7 oz | No time limitations. 3 days, forage. Note plant damage precaution in label. |
| | *permethrin (Ambush, Pounce) | 2E 3.2E | 6.4 fl oz 4 fl oz | 0.1 lb | 1 day phi. Not more than 6 applications. |
| | trichlorfon (Dylox) | 80SP | 1 1/4 lb | 1 lb | No time limitation. Not more than 3 applications/season. |
| Aphids | diazinon | 4E | 1 pt | 1/2 lb | No time limitations. |
| | malathion | 5E | 1 1/2 pt | 1 lb | 5 day phi. |
| | *methyl parathion | 4E | 1/2 pt | 1/4 lb | 12 day phi. |
| | (Penncap-M) | 2F | 1 pt | 1/4 lb | 12 day phi. |
| | *parathion | 4E | 1/2 pt | 1/4 lb | 12 day phi. |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| European corn borer | Bacillus thuringiensis (Dipel) | 10G | 10 lbs | 1 lb | No time limitations. |
| | carbaryl (Sevin) | ALL e.g. XLR plus | 2-4 pts | 1-2 lbs | No time limitations. Not Sevin 4-oil. XLR plus is the safest formulation of Sevin for honey bees. |
| | *carbofuran (Furadan) | 4F | 1 pt | 1/2 lb | 7 day phi. No more than four applications. Do not enter field within 14 days without protective clothing. Machine harvest only. Do not graze or harvest stalk within 21 days. |
| | chlorpyrifos (Lorsban) | 15G | 6.7 lb | 1 lb | 35 day phi. |
| | diazinon | 14G | 10 1/2 lbs | 1 1/2 lb | No time limitations. Do not feed treated fodder for 10 days. |
| | *methomyl (Lannate, Nudrin) | 90% SP | 1/2 lb | 7 oz | No time limitations. 3 days, forage. Note plant damage precaution in label. Other formulations restricted use. |
| | *methyl parathion (Penncap-M) | 2F<br>4E | 2 pt<br>1 pt | 1/2 lb | 3 day phi; 12 days, forage or grazing. |
| | *permethrin (Pounce, Ambush) | 3.2E<br>2E | 4 - 8 fl oz<br>6.4-12.8 fl oz | 0.1 - 0.2 lb<br>0.1 - 0.2 lb | 1 day phi. Not more than 6 applications. |
| Corn earworm | carbaryl (Sevin) | ALL e.g. XLR plus | 3-4 pts | 1 1/2-2 lbs | No time limitations. Not Sevin 4-oil. |
| | diazinon | AG500 | 2-2 1/2 pts | 1 - 1 1/4 lbs | No time limitations. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 1 day phi. |
| | methomyl (Lannate, Nudrin) | 90% SP | 1/4-1/2 lb | 5-7 oz | No time limitations. 3 days, forage. Note plant damage |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | | | | | precaution in label. Other formulations are restricted use. |
| | *methyl parathion (Penncap-M) | 2F | 2 pts | 1/2 lb | 3 day phi. 12 days, forage or grazing. Highly toxic to honey bees. |
| | *parathion | 4E<br>8E | 1/2 pt<br>1/4 pt | 1/4 lb | 12 day phi. |
| | *permethrin (Pounce, Ambush) | 3.2E<br>2E | 4 fl oz<br>6.4-12.8 fl oz | 0.1 lb | 1 day phi. Not more than 6 applications. |
| Corn rootworm adults | carbaryl (Sevin) | XLR plus | 2 pt | 1 lb | No time limitations. |
| | diazinon | 4E | 1/2-1 pt | 1/4-1/2 lb | No time limitations. |

## SMALL GRAIN

| Insect | Insecticide | Formulation Recomm. | Formulation Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Aphids | *disulfoton (DiSyston) | 8E | 1/4 - 3/4 pt | 1/4 - 3/4 lb | 30 day phi, for wheat only, do not graze. |
| | malathion | 5E | 1 1/2 pt | 1 lb | 7 day phi. |
| | *methyl parathion | 4E | 1/2 pt | 1/4 lb | 12 day phi. |
| | *methyl parathion (Penncap-M) | 4E<br>2F | 3/4 - 1 pt<br>1 1/2 - 2 pt | 3/8 - 1/2 lb | 15 day phi. |
| | *parathion | 8E | 1/4 pt | 1/4 lb | 15 day phi. |

Treatment most economical before heading with more than 25 aphids per 6" stem (15 greenbugs) or with 35 aphids/stem from 6" to boot. Do not treat after heading as there will be no yield change.

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| Armyworm, cutworms | *methomyl (Lannate, Nudrin) | All e.g. 90% SP | 3/8 - 3/4 lb | 1/4 - 1/2 lb | 7 day phi. |
| | *parathion | 8E | 1/4 - 3/8 pt | 1/4 - 3/8 lb | 12 day phi. |
| | *methyl parathion | 4E | 1 pt | 1/2 lb | 12 day phi. |
| | (Penncap-M) | 2F | 2 pt | 1/2 lb | 15 day phi. |
| | trichlorfon (Dylox) | 80SP | 1 1/4 lb | 1 lb | 21 day phi, maximum of 3 applications. |

Treat when number of worms exceeds 5 per sq. ft. For armyworm control in non-crop land see p.

| | | | | | |
|---|---|---|---|---|---|
| Grasshoppers | acephate (Orthene) | 75W | 1/4 lb | 1/6 lb | Wheat only. |
| | *carbofuran (Furadan) | 4F | 1/4 - 1/2 pt | 1/8 - 1/4 lb | Wheat, oats, barley. Do not apply after heading. |
| | dimethoate (Cygon) | 4E | 1/2 - 1 pt | 1/4 - 1/2 lb | Wheat only, 60 day phi. |
| | malathion | 5E | 1 1/2 pt | 1 lb | 7 day phi. |
| | *methyl parathion | 4E | 1 pt | 1/2 lb | 15 day phi. |
| | (Penncap-M) | 2F | 2 pts | | |

Treat when more than 8 per sq. yd. in field or more than 20 in margins.

| | | | | | |
|---|---|---|---|---|---|
| Wireworms | lindane | | | 1 oz per bu. | Seed treatments only. |

## SOYBEANS

| Insect | Insecticide | Formulation Recomm. | Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Seed corn maggot | diazinon | | See Label | 1/4 oz per bu. | Seed treatment only. |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| Bean leaf beetle, | acephate (Orthene) | 75W | 2/3 lb | 0.5 lb | 14 day phi. |
| flea beetles | carbaryl (Sevin) | All e.g. XLR | 1 - 2 pts | 1/2 - 1 lb | No time limitations. |
| blister beetle | chlorpyrifos (Lorsban) | 4E | 1 - 2 pts | 1/2 - 1 lb | 28 day phi. |
| | dimethoate (Cygon) | 4E | 1 pt | 0.5 lb | 7 day phi. |
| | | 2.67E | 1.5 pt | 1/2 lb | 7 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 21 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 1 pt | 1/2 lb | 20 day phi. |
| | *permethrin (Ambush, | 2E | 3.2-6.4 fl oz | 0.05-0.10 | 60 day phi. |
| | Pounce) | 3.2E | 2 - 4 fl oz | 0.05-0.10 | 60 day phi. |
| | Treat when defoliation exceeds 50% during seedling stages, 25% during pod fill, or when pod feeding is extensive. | | | | |
| Cutworms, | carbaryl (Sevin) | All e.g. XLR | - 3 pts | 1 1/2 lb | No time limitations. |
| | chlorpyrifos (Lorsban) | 4E | 1 - 2 pts | 1/2 - 1 lb | 28 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 21 day phi. |
| | *permethrin (Ambush, | 2E | 6.4 fl oz | 0.1 lb | 60 day phi. |
| | Pounce) | 3.2E | 4 fl oz | | |
| | thiodicarb (Larvin) | 3.2E | 1 1/4-1 7/8 pt | 1/2 - 3/4 lb | 28 day phi. Do not feed forage to livestock. |
| | *tralomethrin (Scout) | 0.3E | 6.4 - 8 fl oz | .015-.019 | 21 day phi. Do not graze or feed treated forage. |
| | Treat if 20% of the plants cut, stand has gaps of 1 foot or more, and cutworms are present. | | | | |
| Potato leafhopper | carbaryl (Sevin) | All e.g. XLR | 2 pts | 1 lb | No limitations. |
| | *fenvalerate (Pydrin) | 2.4E | 2 2/3 fl oz | 0.05 lb | 21 day phi. |
| | malathion (Cythion) | 5E | 1 1/2 pt | 1 lb | 7 day phi. |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | *methyl parathion (Penncap-M) | 2F | 1/2 - 1 1/2 pt | 1/4-3/4 lb | 20 day phi. |
| | *permethrin (Ambush, Pounce) | 2E | 3.2-6.4 fl oz | .05-.1 | 60 day phi. |
| | | 3.2E | 2-4 fl oz | .05-.1 | 60 day phi. |
| Green cloverworm | acephate (Orthene) | 75W | 2/3 lb | 1/2 lb | 14 day phi. |
| | <u>Bacillus</u> <u>thuringiensis</u> (Dipel, Thuricide, Sok Bt, Clean Crop BT) | | | | As labeled. |
| | carbaryl (Sevin) | All | e.g. XLR - 1 pt | 1/2 lb | No limitations. |
| | chlorpyrifos (Lorsban) | 4E | 1/2 - 1 pt | 1/4 - 1/2 lb | 28 day phi. |
| | dimethoate (Cygon) | 4E | 1/2 - 1 pt | 1/4 - 1/2 lb | 7 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 2 2/3 fl oz | 0.05 lb | 21 day phi. |
| | malathion (Cythion) | 5E | 1 1/2 pt | 1 lb | No time limitation. |
| | *methomyl (Lannate, Nudrin) | All | e.g. 1.8L-1pt | 1/4 lb | 14 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 1 pt | 1/2 lb | 20 day phi. |
| | *permethrin (Ambush, Pounce) | 2E | 3.2 fl oz | 0.05 lb | 60 day phi. |
| | | 3.2E | 2 fl oz | | |
| | thiodicarb (Larvin) | 3.2E | 5/8 - 1 pt | 1/4 - 4/10 lb | 28 day phi. Do not feed forage to livestock. |
| | *tralomethrin (Scout) | 0.3E | 6 - 7 fl oz | .014-.016 lb | 21 day phi. Do not graze or feed treated forage. |
| | Treat when worms number more than 9 per row ft until first bloom (V7-R1), 19 per row ft during full bloom (R2-R3) or 15 per row foot during podfill (R4-R6). | | | | |
| Spider mites | carbophenothion (Trithion) | 8E | 1/2 pt | 1/2 lb | 7 day phi. Do not feed treated foliage. |
| | dimethoate (Cygon) | 4E | 1 pt | 1/2 lb | 21 day phi (5 days to feed livestock). |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| Woolly bears | chlorpyrifos (Lorsban) | 4E | 1 - 2 pt | 1/2 - 1 lb | 28 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 21 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 2 - 3 pt | 1/2 - 3/4 lb | 20 day phi. |

Treat if defoliation exceeds 15% during podfill. Do not treat if podfill completed (R6).

| | | | | | |
|---|---|---|---|---|---|
| Grasshoppers | acephate (Orthene) | 75W | 3/8 - 3/4 lb | 1/4 - 1/2 lb | 14 day phi. Do not feed foliage. |
| | carbaryl (Sevin) | All e.g. XLR | 3 pts | 1 1/2 lb | No limitations. |
| | *carbofuran (Furadan) | 4F | 1/4 - 1/2 pt | 1/8 - 1/4 | |
| | chlorpyrifos (Lorsban) | 4E | 1/2 - 1 pt | 1/4 - 1/2 lb | 28 day phi. |
| | dimethoate (Cygon, Defend) | 4E | 1/2 - 1 pt | 1/4 - 1/2 lb | 7 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3-10 2/3 fl oz | .1 - .2 | 21 day phi. |
| | *methyl parathion (Penncap-M) | 2F | 1 - 3 pt | 1/4 - 3/4 | 20 day phi. |
| | *tralomethrin (Scout) | 0.3E | 6.4 - 8 fl oz | .015-.019 | 21 day phi. Do not graze or feed treated forage. |

Treat early when small grasshoppers exceed 20 per sq. yd. in field margins or 8 per sq. yd. infield.

## SUGARBEET

| Insect | Insecticide | Formulation Recomm. | Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Webworm | carbaryl (Sevin) | All e.g. XLR plus | 3 pts | 1 1/2 lb | 14 day phi, tops. |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | endosulfan (Thiodan) | 3E | 2 2/3 pts | 1 lb | Do not feed tops. |
| | *parathion | 8E | 1/4 - 1/2 pt | 1/4 - 1/2 lb | 20 day phi. |
| | trichlorfon (Dylox) | 80SP | 1 1/4 lb | 1 lb | 14 day phi. |
| | The action level is 1-2 worms on 50-75% of the leaves. | | | | |
| Spider mites | carbophenothion (Trithion) | 8E | 1 1/2 pt | 1 1/2 lb | 7 day phi. |
| | dimethoate (Cygon) | 4E | 1 pt | 1/2 lb | 7 day phi. |
| | disulfoton (DiSyston) | 8E | 1 pt | 1 lb | 30 day phi. |
| Cutworms | carbaryl (Sevin) | All e.g. XLR plus | 4 pts | 2 lb spray | 14 day phi, tops, bait formulation preferred. |
| | | e.g. 20% bait | 5-10 lb | 1-2 lb bait | |
| | chlorpyrifos (Lorsban) | 15G | 8-16 oz/1000 row ft. | 1.2-2.4 oz/ 1000 row ft. | Row treatment at planting time. |
| | | 4E | 2 pts | 1 lb | Broadcast foliar spray. |
| | trichlorfon (Dylox) | 80SP | 20 oz | 1 lb | 14 day phi. |
| | | | (per 1000 row ft.) | | |
| Root maggots | *aldicarb (Temik) | 15G | 6.5-9.5 oz | 1.2 oz = 1 lb in 40" rows | Apply in 2-4" band at planting and incorporate. |
| | | | 4.3 oz | | Modified in-furrow. |
| | *carbofuran (Furadan) | 15G | 4.3-5.3 oz | | Modified in-furrow. |
| | chlorpyrifos (Lorsban) | 15G | 4.5-9 oz | All | In furrow treatment. Modified in-furrow has activity against cutworms. |
| | diazinon | 14G | 4.7-9.4 oz | same as above | Apply in 7" band or as a furrow treatment after seed is covered. |
| | *fonofos (Dyfonate) | 20G | 3.5-5.0 oz | | Apply in 5-7" band and lightly incorporate. Do not place in |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | | | | | contact with seed. |
| | *terbufos (Counter) | 15G | 4 - 8 oz | | Apply in 5-7" band and lightly incorporate. Do not place in contact with seed. |
| Wireworms | *terbufos (Counter) | 15G | 4-8 oz/1000 row ft. | | Banded in 7" band & incorporate. |
| | diazinon | 14G | 14.3-28.6 lb | 2 - 4 lbs | Broadcast incorporated. |
| | *fonofos (Dyfonate) | 20G | 20 lb | 4 lbs | Soil treatment preplant. |
| | lindane | | | 1 oz per bu. | Seed treatment only. |
| Grasshoppers | carbaryl | 4F-XLR | 1 - 3 pt | 1/2-1 1/2 lb | |
| | malathion | 5E | 3 pt | 1 2/3 lb | |
| | " | ULV | 8 fl oz | 7.2 oz | |
| | methyl parathion | 4E | 1/2-3/4 pt | 4 - 6 oz | |
| | (Penncap-M) | 2F | 1-1 1/2 pt | 4 - 6 oz | |

## SUNFLOWER

| Insect | Insecticide | Formulation Recomm. | Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Wireworm | lindane | See label. | | 1/2 oz | (2 3/4 oz DB green per bu.) seed treatment. |
| Cutworm | carbaryl (Sevin) | 5 or 20% B | 20 or 5 lb | 1 lb | Moisture is needed for best efficacy. |
| | chlorpyrifos (Lorsban) | 4E | 2 pts | 1 lb | Rescue treatment with as much water as practical. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | Treat when there is more than 1 cutworm per 2 sq. ft. and before plant population goes below 75% of that recommended for area. Granular preventive treatments are not normally economical. | | | | |
| Grasshoppers | carbaryl (Sevin) | All e.g. XLR plus | 2-3 pts | 1 - 1 1/2 lb | 60 day phi. |
| | *carbofuran (Furadan) | 4F | 1/4 - 1/2 pt | 1/8 - 1/4 lb | 28 day phi. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 42 day phi. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3-10 2/3 fl oz | 0.1 - 0.2 lb | 28 day phi. |
| | Treat before 25% defoliation at all plant stages, irrespective of insect stage. | | | | |
| Sunflower beetle | *carbofuran (Furadan) | 4F | 1/4 - 1/2 pt | 1/8 - 1/4 lb | Lower rates will provide 90% control. |
| | *fenvalerate | 2.4E | 1/2-1 1/2 fl oz | .01-0.03 lb | 240-80 acres per gallon E. |
| | Two adult sunflower beetles per 4 leaf plant or 15 SB larvae per plant will cause 25% or more defoliation. Do not exceed 25% defoliation. Ground application banded on row at last cultivation is most economical treatment. | | | | |
| Thistle caterpillar | *fenvalerate (Pydrin) | 2.4E | 5 1/3 fl oz | 0.1 lb | 28 day phi. |
| | carbaryl (Sevin) | XLR plus | 2 - 4 pts | 1 - 2 lbs | 60 day phi prior to harvest. |
| | Do not exceed 25% defoliation. | | | | |
| Black and sunflower stem weevil | Extensive trials in 1982-1986 suggest we do not improve yields enough to recommend treatment with soil systemic. However if action level of 1 adult spotted stem weevil per plant is exceeded, an aerial application of .1-.2 lb fenvalerate (Pydrin) may be worthwhile. | | | | |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

| | | | | | |
|---|---|---|---|---|---|
| | Action level = 1 adults per plant at 10 to 20 leaf stage. Droughty fields are most subject to stem weevil injury. Fields with adequate moisture show no yield effects. | | | | |
| Sunflower midge | Control with insecticides has been unsuccessful and attempts are not recommended. Use tolerant sunflower hybrids (AD-MR-1953- Varietal Trials of Farm Crops) and delay planting until late May or early June. | | | | |
| Sunflower moth and banded sunflower moth larvae | *carbofuran (Furadan) | 4F | 1 pt | 1/2 lb | 28 day phi, 14 days before reentry. |
| | chlorpyrifos (Lorsban) | 4E | 1 pt | 1/2 lb | 42 day phi. |
| | *fenvalerate | 2.4E | 10 2/3 fl oz | .2 lb | 30 day phi. |
| | *methyl parathion | 4E | 1 1/2 - 2 pt | 3/4 - 1 lb | 30 day phi. |
| | DO NOT TREAT WHEN FORAGING BEES ARE IN FIELD. | | | | |
| | Treat with 2 adult/sunflower moths per 5 plants or when banded moth is noticeable in field margins. Application when between 3 and 5 plants have first made florets extended (30-50% bloom) provides best control. | | | | |
| Sunflower seed weevil | *carbofuran (Furadan) | 4F | 1 pt | 1/2 lb | 28 day phi, 14 days before reentry. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3-10 2/3 | 0.1-0.2 lb | 30 day phi. |
| | *methyl parathion | 4E | 1 - 2 pt | 1/2 - 1 lb | 30 day phi. |
| | DO NOT TREAT WHEN FORAGING BEES ARE IN FIELD. | | | | |
| | Treat when between 3 and 5 of ten plants have a ring of female flowers in bloom. Action level for oil hybrids is 10 to 20 weevils per plant, and confection with 2 to 4 weevils per plant. Respray if action level is exceeded. | | | | |

* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

**NON-CROP LAND**
(Pasture, rangeland, roadsides, waste lands, etc.)

| Insect | Insecticide | Formulation Recomm. | Formulation Product/acre | Dosage | Limitations |
|---|---|---|---|---|---|
| Armyworm | carbaryl (Sevin) | XLR plus | 2-3 pts | 1-1 1/2 lbs | No limitations. |
| | *fenvalerate (Pydrin) | 2.4E | 5 1/3-10 2/3 fl oz | 0.1-0.2 lbs | |
| Grasshoppers | carbaryl (Sevin) | 4-oil | 1/2-1 1.2 pts | 1/2-1 1/2 lbs | No limitations. |
| | *fenvalerate (Pydrin) | 2.4E | 2 2/3-5 1/3 fl oz | .05 - .1 lb | |
| | malathion (Cythion) | ULV | 1/2 pt | 1/2 lb | ULV conc. |
| | *methyl parathion (Penncap-M) | 4E | 1-3 pts | 1/2-1 1/2 lbs | |



* Restricted-use material. Post treated areas when required by label. Check label for re-entry interval.

# DISEASES OF WHEAT
# 1986
# MINNESOTA

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When you plant your wheat crop what is your yield expectation? Does your yield measure up to your production inputs? If your fields are 15% to 20% less than expected you may be experiencing this loss because of cereal leaf spot diseases. The 1986 crop season was very favorable for the diseases of cereals. The techniques for controlling cereal leaf spot diseases, the in-field research has been carried out for at least 20 years, the use of this disease control system is up to you.

Several natural phenomena that may restrict wheat yield occurred during the 1986 growing season. Wet weather delayed planting and favored many of the cereal diseases. Late planting, after May 15th is known to reduce yields. The wet weather favored early disease out breaks, from the southern great plains to Minnesota. Early in the season the crop looked good, and expectations for a good crop prevailed. What happened?

The 1986 growing season was also wet in the lower great plains, in that area many growers plant leaf rust susceptible varieties, probably because of yield expectations and because they have not had an epidemic of leaf rust for many years. The early wet conditions in 1986 allowed leaf rust to develop rapidly on susceptible varieties. The disease, spread by windborne spores moved up the great plains, through Minnesota, North Dakota and into Canada.

The Minnesota crop, for most parts was planted late. The late planting, in itself will result in reduced yields in addition the late planting pushed back the maturity of the crop into more favorable plant disease conditions. Often the wheat crop escapes serious disease situations because it matures before the diseases get a good start. This year we lost the escape system, and financial constraints may have limited the use of fungicides to control cereal diseases. This last restraint may have accounted for 20 or more bushels per acre less than the expected yields.

Tan spot was more severe than usual, especially where wheat was planted on wheat. Tan spot and Septoria leaf blotch attacked the flag leaf throughout the season.

A new player this year was leaf rust. Most of our varieties are resistant to leaf rust, however, they are not immune. With the prevailing epidemic in the great plains our crop received excessive wind borne inoculum (spores). The crop was late and the environment was favorable for disease infections to occur. Resistant type infections did occur on our resistant varieties, such infections do reduce yields. If susceptible varieties had been grown, this infection could have resulted in a major crop failure. However, leaf rust added to the overall crop loss from disease.

The head blight disease, Scab usually makes a short appearance each year, infecting a few florets during the flowering period. The weather usually turns warm and dry so the disease does not spread. With the late crop and continued wetting of the heads by either rain or dew the disease continued through the season.

Scab was much more severe this year than we normally experience. All varieties are susceptible to this disease. The fungus that causes Scab persists on infected debris from the previous wheat crop. However, it also survives on corn debris. This fungus causes stock rot on corn. Therefore, with more corn being grown in the wheat area we may expect to find that Scab will become more of a problem.

The 1986 season produced some good yields (60-70 bu/a) and some poor yields (20-30 bu/a), weather and diseases were major factors as usual.

Growers can keep plant diseases in check if plant diseases are perceived as a problem. Disease control practices, e.g. resistant varieties, seed treatment, crop rotation and foliar fungicide treatment, have been developed. It is now up to the grower to use such practices to the best advantage.

Control of the cereal leaf spot disease has been investigated, reported and practiced for more than 20 years. Proper fungicide application will reduce crop loss resulting from the various leaf spotting diseases.

## SUGAR BEETS

Disease control practices can and do work if no short-cuts are taken. Early detection is important, proper application is essential for chemical treatments to be beneficial. We have been extremely concerned about variety selection, fungicide selection and rightly so however, the application technique is just as important. Some aerial application of less than 5 gallons per acre were observed, giving less than adequate disease control. The general aerial and ground applications were successful in keeping the Cercospora leaf spot disease in check this year.

The Cercospora leaf spot decision model, where used in 1985 worked very favorably for growers. In many beet growing areas the model did not identify the need for fungicide treatment, thus saving a considerable cost to growers.

Growers and Ag. Service persons should become aquainted with the model, so that a good disease control program can be maintained.

## POTATOES

Verticillium wilt is no longer only a disease problem in our area, now it is recognized as a nation-wide disease problem on potatoes.

In the simplest form, cleaning-up this disease problem is going to be expensive. The wilt fungus seems to do quite well living in the soil. However, the wilt fungus really makes its mark when one examines the infected plant debris. This may well be the important factor in the success of wilts rise to prominence in the potato disease world.

It is quite apparent that wilt got it start with the variety Kennebec. Very susceptible, sort of a "Typhoid-Mary" syndrome. The variety came on when Mercury seed treatment went out. It was widely grown especially as the processing industry developed. Crop rotation practices were changing, from potatoes one out of four years to once out of two years. Some growers even went to mono-culture. Also there were no restrictions for wilt on seed.

Verticillium reflects its presence by lowering yield quality. There may be total yield reduction, there is definitely tuber size (quality) reduction and internal vascular necrosis.

Can wilt be controlled? It would appear that many things can be done to reduce the losses resulting from wilt. Control will require a major effort by all parts of the industry.

In the field, the primary source of the disease, infected potato vines should be destroyed, after harvest. Crop rotation will have to be stretched out to 3 or 4 years, until such a time that the inoculum potential in the field has been reduced. Disease resistant varieties will have to be worked into the system. Seed stocks will have to be cleaned up. Last but not least, ultra susceptible varieties should not be grown.

Soil fumigation can reduce the crop loss caused by Verticillium wilt. Even though the results of soil fumigation are economical, It does not appear that fumigation alone will solve the problem. The inoculum going back into the soil from infected stems must be eliminated. Then we should find much better results from soil fumigation.

Wilt resistance has been identified in the Minnesota Potato Breeding materials. As this material becomes a new variety, the grower will have to still exercise disease control practices to reduce the amount of disease inoculum or these varieties will also succumb to the disease.

**TABLE 1. RANKING OF POTATO VARIETIES AS TO SOURCE OF INOCULUM OF VERTICILLIUM SPECIES ISOLATED FROM STEMS (2 YEARS).**

| Variety | *V. Albo-Atrum* Rank | *V. Albo-Atrum* Cor./Cof. | *V. Dahliae* Rank | *V. Dahliae* Cor./Cof. |
|---|---|---|---|---|
| Red Pontiac | 1 | 11.37 | 8 | 5.75 |
| Superior | 2 | 9.87 | 4 | 8.25 |
| Irish Cobbler | 3 | 9.05 | 3 | 9.00 |
| Kennebec | 4 | 8.25 | 2 | 9.75 |
| Norgold Russet | 5 | 8.25 | 9 | 4.62 |
| Russet Burbank | 6 | 7.62 | 1 | 11.25 |
| Norchip | 7 | 6.62 | 6 | 6.88 |
| Norland | 8 | 5.37 | 7 | 6.37 |
| Anoka | 9 | 4.75 | 10 | 3.12 |
| Red La Soda | 10 | 2.75 | 11 | 2.37 |
| La Rouge | 11 | 2.12 | 12 | 2.12 |
| Hunter | 12 | 1.62 | 5 | 7.75 |

## FUNGICIDES[1/] FOR USE ON FIELD CROPS
## CEREALS
## SEED TREATMENT - WHEAT, BARLEY, AND OATS

| COMMON NAME | TRADE NAMES | BUNT CONTROL | SEEDLING BLIGHT CONTROL | REMARK |
|---|---|---|---|---|
| Captan | Captan<br>Orthocide<br>Evershield<br>(Several other names) | | G** | Combination with maneb or zineb for bunt. |
| Captan-HCB | Ortho seed protectant | G | G | |
| Carboxin | Vitavax | | | For control of loose smut |
| Carboxin & seedling Thiram | Vitavax 200 | F | F | For bunt, Evershield blight and loose smut control. |
| Imazalil | Fecundal<br>Double R | | G | For seedling blights. and Root Rots. |
| Maneb | ABSCO DB Green L<br>ABSCO DB Yellow cover-up<br>Granol NM | F | G | DB Green & Granol NM are combined with Lindane |
| Maneb | Granox NM | G | G | |
| PCNB | Terra-coat<br>Terra-coat | G<br>G | F<br>F | Combined with Terrozol<br>Combined with Terrozol |
| Polyram | | F | G | |
| TCMTB | Busan<br>(cover-up L) | G | F | |
| Thiram | Arasan-75<br>Evershield Thiram | F<br>F | G<br>G | |

* Seed injury may occur if high moisture seed is treated and stored.
** F = Control Fair
G = Control Good

1/ There may be other seed treatment fungicides on the market that I am not aware of that are also satisfactory for treating cereal seed.

FUNGICIDES[1/] FOR USE ON FIELD CROPS (CONTINUED)

## CEREALS

| Cereal Leaf Diseases | | Remarks |
|---|---|---|
| Dithane M-45<br>Manzate 200<br>Maneb<br>Zineb<br>Kocide 101 | Rusts and Leaf Spots | Apply by air, using minimum of 5 gallons of water per acre, and spread-sticker per label. See label rate and limitations. |
| Bayleton | Rusts (leaf, stem, stripe) and mildew. | |
| Benlate & Manzate 200 | Powdery Mildew, leaf rust, Helminthosporium leaf blight, Septoria leaf, Tan spot and glume blotch. | A tank mix - see label for rates. |
| Tilt | (Same) | Registration Pending. |

## POTATOES

### Seed Piece Treatment

| | |
|---|---|
| Captan<br>Orthocide Plus<br>(Captan + Mertect)<br>Maneb<br>Polyram<br>Zineb 80%<br>Dust Treat T<br>(Zineb + Streptomycin)<br>(Maneb & Streptomycin)<br>Tops - 2.5 D | See label for rates and limitations. |

### Late Blight and Early Blight

| | |
|---|---|
| Bravo<br>Copper<br>Kocide 101<br>Difolatan<br>Duter (no spreader sticker)<br>AGSCO TN IV<br>Mancozeb<br>Dithane M-45 | See label for rates and limitations |

**POTATOES** (continued)

**Late Blight and Early Blight** (continued)

| | |
|---|---|
| Manzate 200 | |
| Maneb | |
| Dithane M-22 | |
| Manzate | |
| Zineb | |
| Polyram | |
| Blight Out (Polyram + Maneb) | |
| Ridomil MZ | A systemic fungicide especially good for Late Blight, maneb is added for Early Blight protection. Use as needed, Late Blight has been able to develop resistance when excessive applications have been made. |

## SUGAR BEETS

### Seed Treatment

| See Label for Rates & Precautionary Instructions | | For Control of Damping-Off Aphanomyces | Pythium | Phoma | Rhizoctonia | Remarks |
|---|---|---|---|---|---|---|
| Captan 35.2% | Slurry | - | - | - | - | General Seed Treatment |
| Demosan 65W | Slurry | - | G | - | G | May be used as a supplemental treatment |
| Lesan | Slurry | E | E | P | P | May need 6 oz. on high |

**NOTE:** For maximum protection use with a fungicide that controls Rhizoctonia & Phoma.
**CAUTION:** See label for care in handling.

| | | Aphanomyces | Pythium | Phoma | Rhizoctonia | Remarks |
|---|---|---|---|---|---|---|
| Maneb 80% Dithane | drillbox | - | G | - | G | |
| Maneb + Zinc 80% Dithane M-22 Special | drillbox | - | G | - | G | |
| PCNB + Etirdiazole Terra-coat 1-205 | liquid or slurry | G | G | F | E | |
| Terra-coat SD-205 | slurry | G | G | F | E | |
| Thiram Arasan 50 Red | drillbox or Dust | - | - | G | G | |
| Arasan 50 Red ND | Dust | - | - | G | G | |

**P = Poor, F = Fair, G = Good, E = Excellent, - = No Data.**

**Cercospora Leaf Spot**

Control requires - early irregular applications, at recommended rates.

| Copper | Remarks |
|---|---|
| Kocide 101, Champion<br>Kocide 606, Champion Flowable | |
| **Mancozeb**<br>Dithane M-45<br>Dithane 745<br>Flowable<br>Manzate-200<br>Pencozeb 200 Flowable | For all fungicides used see label for rate and limitations. Do not use less than minimum rate, during favorable conditions of infection the spray schedule may be closed-up. When leaves are wet for 8 1/2 continuous hours, temperatures above $62^{o}$ (optimum $75^{o}$) conditions are favorable for infection. |
| **Maneb**<br>Dithane M-22 Special<br>Maneb<br>AGSCO MN Flowable | |
| **Metiram + Maneb**<br>Blite-Out | |
| **Triphenyl Tin**<br>Hydroxide<br>Duter Flowable 30 | 20 ounce rate, at 5-7 day intervals, during hot, humid days, may result in some leaf injury. Follow schedule on the label. |
| **AGSCO IV**<br>Super Tin<br>Triple Tin 4L | |

## Powdery Mildew

| Fungicides for Powdery Mildew Control | Remarks |
|---|---|
| Sulfur<br>*BIG 8 that is<br>Flowable 64%<br><br>Magnetic 6<br>Flowable 51%<br><br>Flowable 52%<br><br>TOP-COP + Sulfur | Apply sulfur if mildew appears by mid-August. One Application usually gives adequate protection for 4 weeks. |
| **Copper** | |
| See listing under Cercospora leaf spot | See label for rate and limitations.<br><br>*Can be used in irrigation System. |

## CHEMICALS FOR DISEASE CONTROL IN DRY EDIBLE BEANS

Richard Meronuck

Chemicals are an important tool in controlling the diseases of dry edible beans. A list of the names of a number of chemicals which are effective in controlling some of the most common diseases are listed below.

The diseases caused by fungi are more easily controlled by chemicals than the bacterial blights. Common bacterial blight, a seedborne bacterial disease, is not efficiently controlled by chemicals. There is evidence, however, that coppers will slow down halo blight (seedborne) and brown spot.

Coverage, timing and application rate is very important when applying chemicals. Ground applications should be made with 30-50 gallons of water with 75-125 lbs. pressure. Air applications should be made with no less than 5 gallons/acre.

Many chemical applications have failed because of inadequate coverage, (due to low rates, low pressure or flying too high, etc.). Coverage is especially important with systemics like Benlate and Topsin-M which are restricted to upward movement in the plant. Good canopy penetration is necessary for optimum control using these chemicals. Though coverage is also important for protectant fungicides.

This list contains information which is current but subject to change. To assure appropriate use, **READ THE LABEL** before use, and follow the recommended rates and safety precautions.

### Dry Beans

### Chemicals Labeled for Seed Treatment of Fungus and Bacterial Diseases

**SEED TREATMENT**

| Chemical | Labeled Use | Rate | Company |
|---|---|---|---|
| Agri-Strep 500, or AS-50 Slurry (5%) | halo blight | 50,000 ppm (5%) -83 lb./100 gal. spray or slurry | Merck & Co. Inc. |
| Agrox 2-way | damping off, seed decay, seedling blight | 2 oz./bu. mixed thoroughly with seed in planter box | Chipman Chemicals, Inc. |

| Chemical | Labeled Use | Rate | Company |
|---|---|---|---|
| Agrox 3-way | damping off, seed decay, seedling blight | 3 oz./bu. mixed thoroughly with seed in planter box | Chipman Chemicals, Inc. |
| Agrox D-LPlus | seedling blight, damping off, seed decay | 2 oz./bu./ mixed thoroughly with seed in planter box | Chipman Chemicals, Inc. |
| Captan 400-D, 39.1% | seed decay, damping off, seedling blight | 2 to 3 fl. oz. /100 lb. | Gustafson |
| Hopkins-Bean Seed Treatment | damping off, seedling blight; for use in Michigan, Nebraska, New York, North Dakota, and Wisconsin states only | 3 oz./bu./ mixed thoroughly with seed in planter box | Hopkins |
| Lesan-70-WP | damping off, seed rot | 1 oz./100 lb. seed | Mobay |

## Dry Beans

### Chemicals Labeled for Foliar Spray of Fungus and Bacterial Diseases

**FOLIAR SPRAY**

| Chemical | Labeled Use | Rate | Company |
|---|---|---|---|
| **Benomyl** | | | |
| Benlate | white mold, grey mold | 1.5 to 2 lbs./A at 25%-50% bloom; repeat at peak bloom 14 day PHI. | DuPont |

| Chemical | Labeled Use | Rate | Company |
|---|---|---|---|
| **chlorothalonil** | | | |
| Bravo 500 | rust, anthracnose, downy mildew | 2 to 3 pt./A at early bloom; repeat at 7 to 10 day intervals. 6 week PHI. | SDS Biotech |
| **copper** | | | |
| Citcop 5E | bacterial blights | 3 pt. in 3 gal. water/A. beginning when weather conditions favor disease development and continue at 7 to 10 day intervals to harvest. | Tennessee Chemical Company |
| Tri-Basic Copper Sulfate | angular leaf spot anthracnose bacterial blight, downy mildew | 2 to 4 lb./A. beginning when plants are about 5 inches tall and repeat every 5 to 7 days. | Tennessee Chemical Company |
| Flowable Tri-Basic Copper | bacterial blights | 1 to 2 qt./A. beginning when disease is first expected and repeat at 7 to 10 day intervals. | Tennessee Chemical Company |
| Kocide 101 | halo blight and common blight | 1 to 3 lb./A. beginning when plants are 6 inches high and repeat at 7 to 14 day intervals. | Kocide Chemical Corporation |
| Kocide 606 | halo blight and common blight | 1 1/3 to 4 pt./A. when plants are 6 inches high and and repeat at 7 to 14 day intervals. | Kocide Chemical Corporation |

| Chemical | Labeled Use | Rate | Company |
|---|---|---|---|
| **copper & sulfur** | | | |
| Kocide 404S | halo blight and common blight rust. | 1 to 3 qt./A. when plants are 6 inches High and repeat at | Kocide Chemical Company |
| | NOTE: the first rate is for control of blights the second is for control of rust. | 7 to 14 day intervals 1.5 to 3.0 qt./A. make 3-4 applications at 7-10 day intervals. | |
| **maneb** | | | |
| Maneb 80 | anthracnose, rust | 1.9 lb/A. beginning during early bloom or when disease first appears, then at 4 to 7 day intervals as needed. | Pennwalt Corporation |
| **maneb + zinc** | | | |
| Agsco MN Flowable | anthracnose, downy mildew, rust | 0.8 to 2.4 qt./A. when disease first appears then repeat at 5 to 7 day intervals. | Agsco, Inc. |
| Dithane FZ | anthracnose, downy mildew, rust | 0.8 to 2.4 qt./A. when disease first appears and repeat at 10 day intervals as long as necessary. | Rohm & Haas |
| Dithane M-22 special | downy mildew and rust | 1 to 3 lb./A. when disease first appears and repeat at 7 day intervals. | Rohm & Haas |

| **Chemical** | **Labeled Use** | **Rate** | **Company** |
|---|---|---|---|
| Manex | anthracnose, downy mildew, rust | 1.2 to 1.6 qt./A. 100 gal. spray/A. beginning when plants are small. Repeat at 5 to 7 day intervals. | Griffin Corporation |
| Manzate D | rust | 1.5 to 2.0 lb./A. when disease first appears and repeat at 7 day intervals as needed | DuPont |
| Manzate 200 flowable | anthracnose, downy mildew, rust | 1.2 to 1.6 qt./A. when disease first appears and repeat at 4 to 10 day intervals (7 day intervals for rust) | DuPont |
| **thiophamate methyl** | | | |
| Topsin M-4.5 F | white and grey mold | 30 to 40 fl. oz./A. once at 50% to 70% bloom or 20 to 30 fl. oz./A. twice first application at 10 to 30% bloom and second application 4 to 7 days later or at peak bloom. | Pennwalt |
| **zineb** | | | |
| Dithane Z-78 | anthracnose, downy mildew rust | 3 to 4 lbs./A. when first blossoms appear and repeat at 7 to 14 day intervals to within 7 days of harvest. | Rohm & Haas |

| Chemical | Labeled Use | Rate | Company |
| --- | --- | --- | --- |
| Zineb 75-WP | rust<br>anthracnose | 1.5 to 2 lb./100 gal. of water use 100 to 125 gal. of spray/A beginning when disease first appears and repeat at 4 to 7 day intervals as long as disease threatens. | FMC |

# ROOT-LESION NEMATODE INJURY IN ALFALFA

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## HISTORY

For several years, it was difficult to establish and maintain productive alfalfa stands at the North Central Experiment Station in Grand Rapids, Minnesota. Many alfalfa seedlings either failed to emerge or after emergence they became yellow and stunted, and subsequently died. The surviving stands declined rapidly. Willis and Thompson (1970) reported similar problems with alfalfa stand establishment in Canada were caused by the root-lesion nematode, *Pratylenchus penetrans*. Analysis of soil samples indicated that large populations of the root-lesion nematode were present in the soil at Grand Rapids, Minnesota.

## DIAGNOSIS

Damage caused by root-lesion nematodes is often difficult to diagnose because poor stands and unthrifty plants may be caused by many factors. Usually, nematode damage is associated with spotty areas containing stunted alfalfa plants within an otherwise good stand. However, sometimes the entire stand becomes sparse with subsequent invasion by quackgrass, dandelions, and other weeds.

Typically, *P. penetrans* causes the development of necrotic lesions on seedling roots with destruction of secondary roots. Vegetative growth is stunted and plant death may occur. The surviving plants are unthrifty and stunted with limited fibrous root systems. In order to diagnose damage due to root-lesion nematodes, it is necessary to assay both root and soil samples for the presence of the nematode.

## DISTRIBUTION

Root-lesion nematodes have been identified in association with alfalfa in 12 counties in Minnesota. The largest populations have been observed in North Central and North Eastern Minnesota (200-1500 nematodes $g^{-1}$ fresh root or 116 $cm^{-3}$ soil). However, moderate numbers of root-lesion nematodes were observed in samples collected in South Eastern counties (100-150 $g^{-1}$ fresh root or 116 $cm^{-3}$ soil). Damage threshold levels for the root-lesion nematode (*P. penetrans*) on alfalfa have not been established, though field observations indicate that 200-300 nematodes $g^{-1}$ fresh root are likely to damage alfalfa.

## CHEMICAL CONTROL RESEARCH

In studies conducted at Grand Rapids, Minnesota, carbofuran application prior to seeding reduced populations of *P. penetrans* in alfalfa roots for approximately six weeks (Thies, et al., 1984) and increased alfalfa stand establishment (Sheaffer et al., 1982). Carbofuran increased forage yields in both the seeding year and the following year (Sheaffer, et al., 1982). Carbofuran, a systemic insecticide-nematicide, protects alfalfa from nematodes for 6-8 weeks after seeding. After this period, nematode populations begin to increase in the roots.

## PLANT RESISTANCE

Alfalfa populations with field resistance to the root-lesion nematode have been developed by the Minnesota Alfalfa Breeding Project, Department of Agronomy and Plant Genetics. After further evaluations, these populations may be incorporated into varieties which may be grown in areas where root-lesion nematodes are a constraint to alfalfa production.

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# NEMATODE DISEASES OF CORN AND SOYBEANS

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Nematodes, also called nemas are unsegmented roundworms found in soil, water, plants and animals throughout the world. Of the over 15,000 species described, about 2,200 species are parasites of plants. Minnesota has the following species present on corn: ROOT-LESION, STUBBY-ROOT, LANCE, DAGGER, STUNT and NOW NEEDLE. Plant-parasitic nematodes are usually microscopic, transparent, mobile and worm-like. The adults of several important parasites like the Cyst nematode of soybean are sedentary or immobile. Passive movement of nematodes occurs in water, soil, and infected plant parts. Nemas are also disseminated by wind, animals, tools and vehicles carrying infested soil. Active movement of nemas through soil is very limited. Nematodes are extracted from soil by various procedures and from roots by incubation techniques. Identification is based on anatomical features such as size and shape of stylet and tail, shape of the esophagus and reproductive organs and cuticular patterns. Normally mixtures or parasitic and non-parasitic nemas are found on plant roots.

Virtually all fields will contain more than one species of plant parasitic nematodes. The kinds and numbers of nemas present in the soil is related to the age and condition of the plants, the previous crops, soil type, weather and tillage factors. Damage also reflects the effects of several interacting factors. Feeding by these small parasites decreases the efficiency of the root system in absorbing water and nutrients. Normal root growth disruption causes suppressed growth, chlorosis or other nutrient deficiency symptoms and ultimately lower yields. The degree of damage is related to the cropping history of the field, field preparation (tillage), environmental conditions after plant emergence and especially the initial soil population at planting. In general, older plants are more tolerant and young plants are more susceptible to injury. Any stress factor that will weaken the plant makes them more susceptible to nematode damage.

Plant Parasitic nematodes are "obligate" in that they must feed on living plants to complete their life cycle. All feed on plant cells by puncturing cell walls with a hollow stylet that resembles a minute hypodermic needle, injecting enzymes into cells, and then ingesting the cell contents. Nema damage to plants occurs in two major ways. Root cells are injuried or killed mechanically or chemically (enzyme secretion). This damage makes roots less efficient in absorbing and transporting water and nutrients. In some cases root growth stops. Nematodes also interact with other pathogens (fungi and bacteria) to cause disease complexes that often damage roots more severely than either can do alone. Certain plant nematodes are vectors for and reservoir of plant viruses.

Nematode feeding reduces plant vigor and root growth, lowers the natural resistance of plants to other pathogens and induces root lesions, galls or other deformations. Plant growth is uneven, with stunted, chlorotic plants.

Striking symptoms often are not present, but include 1) stunting, 2) chlorosis or other discoloration, 3) wilting, 4) root lesions-swellings or devitalized root tips (cessation of growth), 5) reduced and discolored root systems, and 6) yield reductions.

Diagnosis should not be made on symptoms solely. Samples for accurate diagnosis must be sent to a competent nematologist. Proper handling of soil and roots is required for accurate determination of nemas present.

**CORN**

In 1986 a new nematode was found in Minnesota damaging corn. The Needle nema, Longidorus spp. is among the most damaging nematode pathogen of corn. This species is known to be a pathogen of corn in many locations around the world and in several locations of the United States. It was reported in Iowa and Illinois and is probably more wide spread than reported. The Needle nema is one of the longest plant parasitic nematode known, reaching 4-8 mm. Its occurrence is localized with dense populations occurring only in sandy soils where damage is obvious soon after seedling emergence. Sparse stands of severely stunted, nutrient deficient plants in the field symptom, while root pruning, commonly observed produces short, stubby, thickened lateral feeder roots and root tips that have slight swellings. This nema occurs in sandy soils and only damages plants in years with a wet spring. Root damage is severe and as soil drys the nema moves deeper in the soil and is not as damaging or as easily found. The nematode was found in soil from Wabasha county and the root symptom suggests that there is an infestation in Stearns county.

**SOYBEAN**

The soybean cyst nematode (SCN) symptom was greatly reduced in 1986 due to the adequate or excessive soil moisture during the growing season. Symptoms such as stunting and yellowing are more pronounced when plants are stressed. Even in the absence of typical symptoms above ground the roots from suspect fields and test plots had moderate to high levels of the soybean cyst nematode. The soybean cyst nematode was discovered in 9 more Iowa counties in 1986. Three of the 9 are just below the Minnesota/Iowa line from about Fairmont to Worthington. The counties in Iowa are Emmet, Dickinson, and Osceola. The three immediately south of these are also reported to have SCN.

A simple, low cost and easy run test procedure to bioassay soil for the SCN presence will be offered by the Minnesota Plant Disease Clinic. The bioassay directions and information on how to test soil for the presence of SCN will be mailed to interested individuals. The cost is expected to be $5.00 and it includes a lab examination of suspect soybean roots for the cyst nematode. If specific numbers of the SCN and other nematodes are needed the cost will be $15.00. The bioassay test is run by the grower and roots, when sent to the clinic will be examined for the presence or absence of SCN. No quantitative measurement will be made, only a + or - rating is given. Details and the kit are available from the Plant Disease Clinic, Department of Plant Pathology, 495 Borlaug Hall, 1991 Buford Circle, University of Minnesota, St. Paul, Minnesota 55108.

## SOYBEAN SEED TREATMENT

Several seed treatments were again applied to soybean seeds, two sources and six fungicides were evaluated at these locations: Crookston, Staples, Morris, Rosemount, Waseca, Lamberton and Wabasso. Several others were planned but unfavorable spring weather prevented or delayed planting. Seed planted was all good quality as determined by germination tests both standard and cold stress. A difference in yield due to seed treatment was not found. Early season stand at some locations was better with certified seed but final stands and yields were not significant. Soybeans are able to compensate for differences in plant populations and this may well be the reason for nonsignificant differences in yield among seed treatments.

Yield loss associated with Phytophthora root rot was detected at one location. The Wabasso site had significant Phytophthora damage when susceptible lines were planted. Race resistant and lines with some field tolerance performed very well. Ridomil applied to the soil in the furrow at planting increased yields of the fully susceptible soybean by 18.3 bus. but the increase in yield was only 3.2 for old Corsoy and 1.3 for Corsoy 79. Hardin yield difference was 2.6 bus. Phytophthora disease was not a factor at the other locations.

# BROWN STEM ROT-THE MINNESOTA STORY

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Brown stem rot (BSR), caused by the fungus Phialophora gregata was reported in the United States in the mid 1940s. Since then the disease has become much more widespread and now is reported present in most soybean producing areas. The disease is hard to detect as outward symptoms are usually not displayed. Infection occurs through the roots, main or lateral and the fungus grows slowly upward in the water conducting vessels. Yield losses and plant death are greatest when cool weather during pod fill is followed by hot dry weather, yet even under this favorable weather pattern symptoms may not be recognized. Since the disease is present in Minnesota, a survey of the southern three tiers of counties was done to determine the prevalence and severity of BSR. The project was funded by a Minnesota Crop Improvement Association research grant.

The soybean growing area surveyed ranged from Lincoln county (NW) to Wabasha county (NE) south to the Minnesota/Iowa line. This area in southern Minneota has 2.9 million acres of soybeans and has the potential for significant levels of infection and related yield loss. Two locations per county were studied to keep the number of sites at a manageable level. The county extension agricultural agent was asked to identify two soybean growers along a predetermined route through the county. Field history forms were sent to each county agent to assist in field location selection (directions) and field history (crop-tillage-yield for the years '80-'86). Agents did not select all sites. About 50% were field selected by the survey person along the predetermined route. The in field selection process required much additional time during sampling as the field history form needed to be filled out locally by the farmer/owner.

The field survey was completed between August 26 and September 10. Each field site was scouted, removing 5 plants at each of 10 sites representative of the field and each of the 50 plant samples were scored for internal stem pith color. A brown pith or vascular stain near the soil line was considered as positive for BSR. The plants sampled were in the R 5 or R 6 stage. Selected positive samples from each field were returned to the lab ( Plant Disease Clinic) for isolation studies. Isolates from each site were confirmed by growing the fungus on agar media to identify the presents of Phialophora gregata. Identification was confirmed by observing fungal growth, measuring spore size and by comparison with known standards.

The survey of 28 counties in southern Minnesota, from Lincoln to Wabasha and south to the Minnesota/Iowa line resulted in positive identification of BSR in 27 counties. The two locations in LeSueur did not test positive for the fungus even when some stems had brown pith present. The prevalence of BSR in the 56 locations was 86%, when based on the presence of brown stem color and 71% when based on the isolation of the fungus from stem tissue. The visual method tends to over estimate the degree of infection. This should be expected as not all causes of brown stem pith are due to BSR infection.

The degree to which field visual symptoms were confirmed by laboratory isolation indicates a range of confidence can be established for the visual test. If a field has 0 to 16 stems out of 100 that have brown pith the confidence score is 36% positive, while 17 to 32 brown pith stems has a confidence score of 85% and if above 33 stems the confidence level is 100%.

The severity of BSR in fields sampled, ranged from none detected to 98% infection. The average level of severity for the survey sites was 32%. This may be of some comfort if your an average farmer but the more important fact is the number of fields found to be infected. Seventy one percent of Minnesota soybean fields in 1986 have the disease confirmed and 58% of these fields are in the severity range of 38 to 98% infection. The loss figures associated with a 40 to 100% infection rate are 6.4 to 16.0 bushels per acre.

Previous crop history of soybeans appears to be the major factor in promoting the severity of BSR. As the number of soybean crops increases from 0 to 3 for the period of 1981 to 1985 the percent infection in a field rose from 3 to 98%. Tillage information on the fields from 1981 to 1985 was some what incomplete but no relation was observed when tillage varied from moldboard plow to chisel to disk to no till. The crop rotation/severity level scores are presented in table one.

Table 1. The severity score (% infection) and crop rotation pattern.

| % Severity | | | Crop Year | | |
|---|---|---|---|---|---|
| 1986 | 1985 | 1984 | 1983 | 1982 | 1981 |
| 98 | S | C | S | C | S |
| 66 | S | C | A | A | ? |
| 64[a] | Nh | S | Nh | S | Nh |
| 42 | Nh | S | Nh | Nh | Nh |
| 21 | Nh | 2/3 S-1/3 Nh[b] | Nh | 1/3 S-2/3 Nh[c] | Nh |
| 0 | 6/7 Nh[d] | 6/7 Nh | 6/7 Nh | Nh | Nh |

a Usually a long term corn/soybean rotation.

b 2/3 S - 1/3 Nh 67% of the time soybeans and 33% of the time a non-host.

c 1/3 S - 2/3 Nh 33% of the time soybeans and 67% of the time a non-host.

d 6/7 Nh 86% of the time a non-host.

S = Soybeans, C = Corn, A = Alfalfa, Nh = Non-host, such as wheat, oats, sweet corn, grain, PIK or hay ? = unknown

# NEW DEVELOPMENTS IN CORN AND SOYBEAN WEED CONTROL

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This year, all of the weed control recommendations have been included in one publication entitled "Cultural and Chemical Weed Control in Field Crops - 1986". The publication discusses weed control in corn, dry beans, flax, forage legumes and grasses, small grains, soybeans, sugarbeets, sunflowers, and perennial weeds. The entire publication is included in this publication.

The only new product for corn weed control in 1986 is tridiphane (Tandem), which is registered to be mixed with atrazine and oil or cyanazine (Bladex 80W or 90DF) to improve postemergence grass weed control. Tandem only enhances weed control; do not use Tandem by itself.

Package mixtures are starting to play a larger role in the corn herbicide market. Package mixtures are combinations of two or more herbicides in one container and are often given a new or unique trade name. Package mixtures are convenient to handle but almost all contain atrazine. Therefore, be sure to calculate how much atrazine you are applying when using these package mixtures. For details on package mix contents and rates of use see Table Cl in the corn weed control guide. Several new package mixtures which have been registered for use are the following: Buctril plus atrazine, Torch Twin Pack, Rhino, Conquest, and Marksman.

Several herbicides received label changes in 1986. The Bicep formulation was changed from 4.5 lb/gal to 6 lb/gal of product and both formulations will be on the market this year. Paraquat will be marketed only by ICI Americas, Inc. as Gramoxone Super. The formulation of paraquat will also change from 1.5 lb/gal to 2 lb/gal. Cyanazine (Bladex) is now registered as a restricted use herbicide. This means that you must be a certified applicator to purchase and apply this product.

In soybeans, several new herbicides have entered the market place. FMC-57020 (Command) has been **relabeled** and the formulation has been changed from 6 lb/gal to 4 lb/gal. **Command is to be used only as a preplant incorporated herbicide.** This change is due to the volatility problems associated with preemergence applications of Command. In this publication see the paper entitled "Command - Problems and Potential in Minnesota" for more details.

DPX-F6025 (Classic) is a postemergence broadleaf herbicide labeled for use in Minnesota. However, Classic cannot be applied to soils with a pH greater than 6.8 due to the carryover potential to sensitive crops (corn, alfalfa, and others). Several soil applied package mixes containing the same active ingredient that is in Classic may be labeled by the 1987 growing season. These package mixes are Preview (Classic + Sencor) and Lorox Plus (Classic + Lorox); these package mixes also have the pH restriction of 6.8.

Another postemergence broadleaf herbicide labeled this year is aciflurofen (Tackle). Tackle has the same active ingredient as Blazer and performs similarly. Lactofen (Cobra) is a postemergence broadleaf herbicide that may be labeled by the 1987 growing season. Cobra has good activity but has the potential to cause serious soybean leaf burn. Watch the Cobra rates and follow the label closely.

Fenoxaprop (Whip) is the only new postemergence grass herbicide that should be labeled for the 1987 season. Whip is an annual grass herbicide with very little perennial grass activity. DPX-46202 (Assure), another postemergence grass herbicide, may be labeled for 1987 but looks doubtful at this time.

Turbo, a package mixture of metribuzin (Sencor) and metolachlor (Dual) has received registration for soybean weed control. By the 1987 growing season it is possible that a trifluralin (Treflan) and Sencor package mix called Salute will also be labeled.

In two separate rulings the Environmental Protection Agency (EPA) has issued an emergency suspension of dinoseb (Dyanap, Premerge Plus, and others) and has issued a report that proposes a restricted use classification for alachlor (Lasso).

According to the EPA, dinoseb's registration was suspended because evidence indicated that exposure of pregnant women to dinoseb during or shortly after field application posed a risk of birth defects to their unborn children. Exposure of male field workers to dinoseb poses the risk of sterility. However, eating plants or plant parts treated with dinoseb does not present a health risk. All useage of dinoseb should be stopped and it should only be disposed of through product recall.

Lasso may become a restricted use herbicide in 1988 because laboratory studies have shown that Lasso causes tumors in laboratory animals when it is fed to them for long periods of time.

# COMMAND - PROBLEMS AND POTENTIAL IN MINNESOTA

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University of Minnesota

FMC-57020 (Command) entered the soybean herbicide market in 1986 labeled for preplant incorporation and preemergence application. Command was a 6 lb/gal formulation in 1986 and was labeled at the rate of 1 to 1.66 pts/A (.75 to 1.25 lb a.i./A) to control most annual grass and some broadleaf weeds; Command is an especially good velvetleaf herbicide. Unfortunately, Command ran into some problems in 1986 that have led to some significant changes in the 1987 Command label. These problems involved the following: mixing, volatility, and carryover to crops planted the next year.

Command has changed from a 6 lb/gal to a 4 lb/gal formulation to eliminate mixing problems. Last year, under certain conditions, Command would crystallize out of solution while it was being mixed in the spray tank. It is believed that the solvent and the high formulation rate contributed to the problem and that changes in the formulation and solvent will correct this problem in 1987.

Preemergence applicaitons of Command to a moist or wet soil surface enhanced the volatilization of Command and allowed it to move, as a vapor, as far as 1/4 to 1/2 mile away from treated soybean fields. The off-target movement of Command is capable of injuring sensitive plants such as apples and peach trees, rose bushes, alfalfa, and oats. Command produces a distinct whitening or yellowing of a sensitive plant's foliage due to the plant's temporary inability to produce chlorophyll. In order to reduce the potential for off-target movement Command must be applied to a dry soil and must be incorporated. The FMC label states that incorporation should be immediate whenever possible but must be done within 3 hours after application. The Elanco label calls for the immediate incorporation of tank mixtures containing Command and ethalfluralin (Sonalan) or trifluralin (Treflan). At the time of this publication, Mobay's Sencor label is calling for incorporation within 3 hours after application of tank mixtures containing Command. Immediate incorporation is still highly recommended. Both one and two pass incorporations are labeled; the object is to incorporate the herbicide thoroughly but no deeper than 3 inches. To reduce volatility and drift problems do not apply Command aerially or through irrigation equipment; do not apply Command within 100 feet of the sensitive plants listed on the label; do not apply within 1,000 feet of the commercial production of vegetables or fruits and nurseries, greenhouses, towns, or subdivisions. In addition, make sure the sprayer is thoroughly cleaned of Command residues before spraying other crops.

University of Minnesota research and on-farm field studies have shown that Command may persist for more than one year in the soil. Do not rotate to sensitive crops such as small grains, corn grown for seed, alfalfa, or other forage legumes the year after application of Command, as crop injury may occur. Whitening of corn from Command carryover has been observed in Minnesota following cold or dry soil conditions, when recommended rates have been exceeded, in overlapping spray swaths, or in sprayer turnaround areas. Whitened corn plants will generally return to a normal green color within a week and corn yield should not be affected unless there was a high rate of overapplication. Calibrate your sprayer before application. Plowing with a moldboard plow reduces the potential for crop injury from residues of Command.

Elanco and Mobay each have labels that include Command as part of a tank mixture. Both labels have at least part of their rate structure positioned below one-half of a pound of active ingredient per acre (.5 lb/A). University of Minnesota research indicates that on medium- to fine-textured soils, rates of .5 lb/A or less of Command may not give adequate velvetleaf control. Addition of metribuzin (Lexone/Sencor) may enhance Command's effect on velvetleaf at rates of .5 lb/a or less, but more research data are needed before definite conclusions can be drawn. Depending upon the soil type, it appears that Command applied within the .5 lb/A to 1.0 lb/A range will give best results.

# Small Grain Weed Control Update - 1986

Beverly R. Durgan
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University of Minnesota

A copy of "Weed Control in Small Grains", revised for 1987, is included in this publication. As of this date, there have been no EPA clearances for new herbicides for weed control in small grains for the 1987 growing season. However, I do anticipate the clearance of at least two new herbicides before the 1987 growing season.

Assert (AC 222,293), an experimental herbicide being developed by American Cyanamid, may receive label clearance for 1987. Assert will control wild oats in the 1 to 4 leaf stage in wheat and barley. Assert also gives excellent control of wild mustard and suppresses wild buckwheat, field pennycress, and kochia. Use rate will probably range from 0.38 to 0.50 lbs active ingredient per acre. Research conducted at the University of Minnesota and at North Dakota State University has shown that certain herbicides may be antagonistic with Assert when tank-mixed. Reduced wild oat control has sometimes been observed when Assert was tank-mixed with amine formulations of 2,4-D or MCPA, dicamba (Banvel), picloram (Tordon) or propanil (Stampede).

Harmony (DPX-M6316), an experimental herbicide being developed by Dupont, is also expected to receive a label clearance for 1987. Research at the University of Minnesota has shown that Harmony will control many annual broadleaf weeds in wheat, barley and oats. Use rate will probably range from 18 to 35 grams active ingredient per acre. Harmony must be applied when weeds are small, less than 4 inches tall, and when the crop is in the 2-leaf stage until boot stage.

## Sunflower Weed Control Update - 1986

Beverly R. Durgan
Extension Agronomist - Weed Control
University of Minnesota

A copy of "Weed Control in Sunflowers", revised for 1987, is included in this publication. As of this date, there have been no EPA clearance for new herbicides for weed control in sunflowers. However, I do anticipate the clearance for two herbicides for use before the 1987 growing season.

Assert (AC 222,293) is an experimental herbicide being developed by American Cyanamid for wild oats and wild mustard control in sunflower. Because wild mustard is such a serious problem in sunflower, Assert was granted a Section 18 - Emergency Exemption in 1986. The use rate for wild mustard control was 0.187 to 0.25 pounds active ingredient per acre. Research at the University of Minnesota has shown that sunflower tolerance and wild mustard control at these rates of Assert are excellent. A Section 18 - Emergency Exemption for wild mustard control has also been requested for the 1987 growing season.

Poast (sethoxydim) is also expected to receive EPA label clearance before the 1987 growing season for postemergence control of annual grasses in sunflower. Poast is currently labeled for annual grass control in soybeans. The use rate will probably be 0.19 to 0.38 pounds active ingredient per acre. University of Minnesota research has shown the sunflower tolerance to Poast is excellent.

# WEED RESISTANCE TO HERBICIDES IN MINNESOTA

Richard Behrens
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University of Minnesota

Herbicide use in Minnesota has been very extensive. It now involves applications to over 15 million acres of cropland each year. The phenoxy herbicides, mainly 2,4-D and MCPA, were the first to be widely used, since the early 1950's, with major usage on small grains and corn. In 1984, phenoxy herbicides were still being used on over 5 million acres in Minnesota. In the 1950's three other herbicide families were discovered and introduced. The amide herbicides, first represented by CDAA (Randox), now includes propachlor (Ramrod) and alachlor (Lasso) and metolachlor (Dual). Usage of these compounds has been increasing for 25 years on corn and soybeans. In excess of 5 million acres are now treated with the amides each year in Minnesota. Members of the triazine family of herbicides represented by atrazine and cyanazine (Bladex), used in corn and metribuzin (Sencor/Lexone) in soybeans, have been used extensively for over 20 years. In 1984 these herbicides were used on approximately 3.5 million acres of corn and soybeans. A final herbicide family, used fairly extensively in Minnesota since the late 1950's, is the thiocarbamate family with EPTC and butylate being the major compounds. In 1984 these herbicides were used on approximately 500,000 acres of corn. The dinitroaniline herbicide family, which includes trifluralin (Treflan), pendimethalin (Prowl) and ethalfluralin (Sonalan), first came into commercial use in the early 1960's and usage has been very extensive for 20 years. Currently, herbicides from this family are used on nearly 4 million acres of soybeans, wheat, and other crops.

I have outlined the extensive, long-term usage of these herbicide families because it is encouraging to know that with such long term widespread usage, we have confirmed resistance of only one weed species, common lambsquarters, to one herbicide family, the triazines, in Minnesota. The case, verified in the winter of 1982 using seed collected in August, 1982, was that of triazine-resistant common lambsquarters found in southeastern Minnesota (Fillmore County). Since then, resistant lambsquarters has been found in Goodhue, Olmsted, and Morrison Counties.

These discoveries have been widely publicized. Minnesota farmers and county agricultural agents have been encouraged to report any weed infestations suspected of being triazine resistant. Since county agent and public awareness of the resistance problem is substantial, the lack of reports on new problem areas indicates to me that the distribution of triazine-resistant common lambsquarters populations is not widespread in Minnesota at this time.

On a world-wide basis there are now about 40 species of weeds that have developed resistance to the triazine herbicides, including many of the most common Minnesota weeds such as smartweed, pigweed, ragweed and the foxtails. However, at this time, there are only a few reports from throughout the world of weed resistance to other herbicides. From within the U.S. the only reports are of a trifluralin-resistant goosegrass in South Carolina and a diuron-resistant common groundsel in the western U.S.

What is the possibility of finding or developing other herbicide-resistant weeds in Minnesota? It is very likely that in the future other herbicide resistant weeds will be discovered in Minnesota. In fact, they are probably here already but in such low numbers that they go unnoticed. Discovery of more triazine-resistant weed species is the most probable because of their widespread occurrence throughout the world. It should be recognized that triazine-resistant weeds still remain sensitive to other herbicides which can be used in their control.

Every effort should be made to prevent or delay the development of herbicide-resistant weeds so that we can continue to use the many excellent herbicides that are now available to us. Intelligent management of crop production will be required to avoid infestations of herbicide resistant weeds. Do not grow the same crop or use the same herbicide in a field year after year. This will allow herbicide-resistant weed strains that are already present to increase until they predominate. Changing to herbicides in another family or rotating to another crop that allows the use of different herbicides will prevent the buildup of resistant weeds. Also, the use of tillage or tillage-herbicide combinations provides diversified weed control that does not allow the resistant strains to multiply undisturbed.

Be on the alert for weed species that are becoming difficult to control. Seed of suspected herbicide resistant weeds can be tested to verify herbicide resistance. Collect a few mature seeds and ask your county agent to forward them to: Extension Agronomist-Weeds, Agronomy Department, University of Minnesota, St. Paul, MN 55108 with information where they were collected and what herbicide was used. Results of the tests and recommendatons on control of the weed will be provided to you.

# Effective and Profitable Weed Control

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University of Minnesota

It is estimated that 96 percent of the corn and soybeans and 89 percent of the spring wheat acres are treated at least once each year with a herbicide. With the cost of herbicides ranging from $2.00 to $40.00 per acre, it is important to get the most effective weed control available.

When planning a weed control program, weed seedling identification should be the first step. Many herbicides need to be applied when weeds are small to be effective; therefore, it is important to accurately identify weed seedlings. Many weeds look similar in the seedling stage, however their control may be quite different. Mapping weed locations in a field can also help to reduce weed control costs. Often it is possible to treat only parts of a field rather than the entire field. Perennial weeds such as Canada thistle and milkweed usually occur in patches. These patches can be spot treated.

Accurate calibration of spray equipment can help reduce weed control costs and increase the effectiveness of the herbicides used. Over applying an herbicide can result in higher chemical costs, potential crop injury, and carryover problems. Under applying an herbicide often results in ineffective weed control and decreased yields due to weed competition.

In row crops, consider applying herbicides in a band over the crop row to help reduce weed control costs. The herbicide rate in the treated area is the same for both a band and broadcast applications; however, with a band application, only a fraction of the total acreage is being treated with a herbicide. If herbicides are applied in a band over the crop row, cultivation will then be needed between the rows to control weeds that were not treated. Therefore, the cost of cultivation, the time it takes, and the possibility of adverse weather conditions that could prevent cultivation also will need to be considered.

Trying to decrease weed control costs by applying below labeled rates of herbicides will not always increase profits. Applying below labeled rates often leads to poor weed control and decreased yields due to weed competition. Use the lower labeled rates when climatic conditions are favorable, and when weeds are small and actively growing.

Do not waste money on herbicide additives that are not needed. Research has shown that additives do not increase the effectiveness of soil applied herbicides. However, many postemergence herbicides do need the addition of an additive for effective weed control. Read the label and use the right additive at the proper rate.

It is possible to reduce weed control expenditures and still maintain an effective weed control program. The time required to evaluate weed control choices from among the many alternatives will be paid back in profitable returns and more effective weed control.

## CULTURAL AND CHEMICAL WEED CONTROL IN FIELD CROPS - 1986

Information in this publication is based on research by the Minnesota Agricultural Experiment Station, other experiment stations and U.S. Department of Agriculture on the effectiveness of cultural practices and chemicals for controlling weeds. The suggested chemical uses in this publication are within clearances established by the U.S. Environmental Protections Agency (EPA).

Herbicides are registered by the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act as amended for uses involving food or feed on the basis of finite chemical tolerances or exemptions from the requirement of tolerances established by the Food and Drug Administration. The Federal Food, Drug, and Cosmetic Act, as amended by Public Law 518 (Miller Amendment), makes liable for seizure any raw agricultural commodity which carries a pesticide residue: 1) for which no exemption or tolerance has been established or 2) which exceeds the tolerance established by the Food and Drug Administration.

Instructions for registered uses of herbicides are given on container labels. Read and follow these label instructions carefully. Use products that are labeled specifically for the intended use. Some formulations of a chemical may not be labeled for certain uses. Persons using herbicides in a manner contrary to the label instructions are subject to penalty under federal and state laws.

This publication is for your information. The University of Minnesota or its officers or employees make no claims or representations that the chemicals discussed will or will not result in residues on agricultural commodities and assume no responsibility for results from using herbicides.

Some registrations are under review; therefore, some uses suggested in this bulletin could change during the year. New information will be available from County Extension Agents as changes occur. The herbicide effectiveness ratings listed in this publication show general comparative control ratings based on field observations. Under unfavorable conditions, any of the herbicides may give unsatisfactory results. Under favorable conditions control may be better than indicated.

Read the label and follow instructions in using herbicides. The EPA classifies herbicides for "general use" or "restricted use." General use herbicides can be used by anyone, and if label directions are followed carefully, there is little chance of harm to humans or the environment. Restricted use herbicides are frequently more toxic than general use herbicides and when they are used there may be a greater chance of harmful effects to humans or the environment. Only certified applicators who receive special training in handling and applying herbicides are allowed to purchase and apply restricted use herbicides. Contact your county agent if you wish to become a certified applicator. For your protection three signal words are used on herbicide labels to indicate different degrees of toxicity of herbicides. Either "Caution" for a slightly toxic, "Warning" for a moderately toxic, or "Danger" for a highly toxic herbicide, will be printed on the label along with an explanation of the specific danger and what precautions should be taken in handling or using the herbicide.

**Rates:** Application rates listed in this publication are broadcast rates and refer to acid equivalent or active ingredient rather than commercial product. In practice, rates will need to be adjusted for varying row widths if applied in bands and for the concentration of the particular product used. See AG-FS-0917 "How to Calculate Herbicide Rates and Calibrate Herbicide Applicators."

**Safety precautions:** Always follow carefully the precautions and use restrictions on the label to help protect the operator, avoid crop injury, and prevent harmful residues in food and feed crops. Use herbicides only on crops specified on the label. Use only the recommended amount of herbicide; applying too much of an herbicide may damage the crop, may be unwise if the crop is to be used for food or feed, and is costly. Apply herbicides only at times specified on the label; observe the recommended intervals between treatments and pasturing or harvesting of crops. Wear goggles, rubber gloves, and other protective clothing as recommended on the label. Prevent drift onto nearby susceptible plants. Return larger quantities of unused herbicides in unopened containers to the manufacturer or store them properly until used. Dispose of empty containers in a safe manner:

1. Triple rinse container thoroughly with water and use the rinse water in the sprayer.

2. Bury small and decomposable containers in approved and supervised sanitary landfills.

3. Send empty metal pesticide containers of 15 gallon capacity or more back to the manufacturer or to professional drum reconditioners.

4. Observe special label instructions relating to disposal.

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Revised for 1986 by B. R. Durgan and J. L. Gunsolus, assistant professors and extension agronomists-weeds and A. G. Dexter, professor and extension sugarbeet weed control specialist. Other staff members concerned with

field crop weed control in the Department of Agronomy and Plant Genetics include C. V. Eberlein, assistant professor; D. L. Wyse professor; and R. N. Andersen, Research Agronomist, Agricultural Research Service, United States Department of Agriculture.

**Read the pesticide label and follow the instructions as a final authority on pesticide use.**

## CHEMICAL WEED CONTROL PRACTICES

The terms listed below are used in this folder to describe herbicide applications:

**Acid equivalent** -- A term used to express a rate or quantity of an acid herbicide.

**Active ingredient** -- A term used to express a rate or quantity of a nonacid herbicide.

**Band application** -- Herbicide applied to a narrow strip centered over the crop row.

**Broadcast application** -- Herbicide applied over entire area.

**Directed spray application** -- Herbicide applied to a band over the row that includes the base of crop plants and the weeds in the row. Spray is directed across the row from nozzles positioned near ground level on each side of the row. This type of application allows use of chemicals that will injure the crop plant if more than a small part of the plant is contacted by spray. Special units that guide from the ground or mount on cultivators must be used.

**Drop-nozzle application** -- Herbicide applied by means of nozzles mounted on extensions below the spray boom to avoid spraying upper parts of the crop plant.

**Formulation** -- Refers to the form in which a herbicide is purchased. Common forms are liquids, granules and wettable powders which contain added ingredients to improve storage, mixing or application characteristics of the herbicides.

**Postemergence application** -- Herbicide applied to the crop and weeds after they emerge.

**Preemergence application** -- Herbicide applied after a crop is planted but before it or weeds emerge.

**Preplanting application** -- Herbicide applied before the crop is planted.

**Rate** -- The amount of active ingredient or acid equivalent of an herbicide applied to the area treated, that is, on a broadcast basis.

**Soil incorporation** -- Mechanical mixing of the herbicide with the soil. Chemicals may be incorporated 2 to 4 inches with a disk or rotary tiller, 1 to 2 inches with a harrow or rotary hoe, or slightly covered with planter attachments. The desired depth of incorporation depends on characteristics of the chemical being used.

## INTEGRATED WEED CONTROL

Effective weed control usually results from a combination of cultural, mechanical, and chemical practices. The ideal combination for each field will depend on a number of considerations including: 1) the crop being grown, 2) the kinds of weeds, 3) the seriousness of the weed infestation, 4) the soil type, 5) the cropping system, and 6) the availability of time and labor.

**Cultural practices** that are optimum for crop growth should be followed. These practices include adequate fertility, optimum stands and row width, and proper seeding date. Tillage operations, if used, should be timed to destroy weeds. Tilling the soil immediately before planting will kill weeds that have germinated, thus giving the crop a competitive advantage and often improving weed control from chemicals that do not control weeds that have germinated.

Early cultivations when weeds are small are most effective. Use a rotary hoe, harrow, or cultivator as soon as weeds begin emerging and are in the "white stage," even if herbicides have been applied. Set cultivators for shallow operation to avoid crop root pruning and to reduce the number of weed seeds brought to the surface. Throw enough soil into the row to cover small weeds. Shallow cultivation should be repeated as necessary to control newly germinated weeds.

Mowing is an effective weed control practice in perennial forage crops and noncropland areas. To be effective, mowing must be done before seeds are formed which means you must mow by the time weeds are in the bud stage or just beginning to bloom. Earlier mowing will reduce weed competition and improve crop yield more than later cutting.

### Selecting Chemicals

Selection of an appropriate chemical or combination of chemicals should be based on consideration of the following factors:

- -- Label approval for use
- -- Use of the crop
- -- Crop and variety tolerance
- -- Potential for soil residues that may affect following crops
- -- Kinds of weeds
- -- Soil texture
- -- pH of soil
- -- Amount of organic matter in the soil
- -- Formulation of the chemical
- -- Application equipment available
- -- Potential for drift problems
- -- Tillage practices
- -- Herbicide performance
- -- Herbicide cost

The information in this publication and on product labels will help you select and use chemicals properly according to the above factors. Proper application of chemicals is essential for obtaining satisfactory results. Follow carefully the suggested rates on labels for specific soil and weed situations. Apply herbicides at the times specified. Delayed applications usually result in poorer weed control and may injure the crop.

Weather conditions will affect herbicide performance. Weed control from soil-applied herbicides may be poor if there is insufficient rain soon after treatment, which will make timely cultivation necessary to control emerging weeds. If rainfall is very heavy, some herbicides may be moved downward in the soil, resulting in poor weed control and/or crop injury. Temperature and moisture conditions affect the weed control and crop injury resulting from herbicides applied postemergence. Observe label precautions regarding weather conditions and crop and weed size when applying herbicides.

**REDUCING WEED CONTROL COSTS**

There are many possibilities for reducing weed control costs while still attaining good weed control. Wise selection of weed control practices and herbicides to fit specific field situations is the key. Identify your weeds and develop an effective, low cost control program that is suitable for the crop you plan to grow. Using band applications of herbicides in row crops, supplemented with cultivation, may save you money. Reducing herbicide rates below those recommended increases the possibility of costly weed control failure. On the other hand, applying herbicides at greater than recommended rates adds unnecessarily to your weed control costs and may result in crop injury or herbicide carryover. Applying herbicides at the proper time and rate with a carefully calibrated applicator provides the best return on your herbicide investment.

**GRANULAR VERSUS SPRAY FORMS OF HERBICIDES**

Several herbicides are available in formulations to be applied as dry granules or as sprays. With a few exceptions, approximately the same weed control can be expected from either form. The cost of granules is usually higher than the cost of an equal amount of the spray form. Distribution of chemicals with granule applicators is sometimes not as uniform as with sprayers, especially on rough ground. In some instances poor distribution has resulted in variable weed control. A wide, flat press wheel or similar attachment on the planter that leaves a level fine surface is desirable for uniform granule application. Chemicals that cause irritation are less irritating in the granular form than in the spray form.

**HERBICIDE MIXTURES**

Herbicide mixtures are used to overcome limitations of single chemicals. Certain mixtures may (1) control more kinds of weeds, (2) give more consistent performance with variable soils and weather conditions, (3) lessen soil residue problems, (4) increase persistence enough to give full-season weed control, or (5) reduce crop injury.

Only those mixtures that have been field tested under local conditions should be used. Use of some mixtures may result in poor weed control or crop injury. Growers or applicators may be responsible for chemical residues in crops, crop injury or lack of weed control resulting from use of unlabeled mixtures.

## CORN

C1. Weed management in corn should be based on an optimum combination of cultural, mechanical, and chemical practices. The most effective and economical weed management system depends on the kinds of weeds in the field, severity of the weed infestation, soil characteristics, tillage practices, crop rotation, selection of herbicide(s) with the highest level of effectiveness at the lowest cost per acre, and availability of time and labor.

### Cultural and Tillage Practices

C2. The development of sound corn production practices that encourages vigorous corn growth and development will increase corn's competitive advantage over weeds. Weeds that germinate before corn planting can be destroyed with tillage operations or herbicides. Killing weeds just before planting gives the young corn seedlings a competitive advantage over the weeds and can improve the performance of preplanting or preemergence herbicides. For effective weed control, herbicides applied preemergence need to be moved into the soil by rainfall before weed seeds germinate. If rainfall has not been sufficient for herbicide activation, control the weed seedlings with a rotary hoe, harrow, or cultivator as soon as they emerge. Cultivation of weed escapes is an effective and economical weed control tool. Cultivation should be done when weeds are small and should be shallow (1 to 2 inches) to avoid corn root damage.

### Crop Rotation Practices

C3. Crop rotation can be an important component of a weeds management program. Most annual grass weeds can be more easily and/or economically managed in soybeans than in corn. The opposite is true for most annual broadleaf weeds. In addition, crop rotation encourages the use of different types (families) of herbicides on the same field over the years. This helps to prevent the accelerated microbial degradation of some herbicides, the residue buildup of some other herbicides, and the buildup of difficult to control weeds. In continuous corn it is particularly advisable to rotate, over the years, through a selection of soil-applied herbicides from different chemical families. Commonly used soil-applied herbicides for corn in different chemcial families are as follows: Acetanilides - alachlor (Lasso), metolachlor (Dual), propachlor (Ramrod); Benzoic acids - dicamba (Banvel); Thiocarbamates - butylate (Sutan+, Genate Plus), EPTC (Eradicane, Eradican Extra); Triazines - atrazine, cyanazine (Bladex), and simazine (Princep).

### Herbicides

C4. Herbicides are the newest and often the most efficient weed management tool. Although herbicides have become a necessity in most corn production systems, far too many growers equate weed management solely with herbicides. Remember that herbicides are only one of the available weed control tools and that weed management is most successful and economical when all the tools for weed control are utilized in an integrated program.

C5. A herbicide or herbicide combination should be selected on the basis of its effectiveness on the different weed species in the field (Table C2). The correct herbicide rate must be used to obtain good weed control results and to minimize corn injury (Table C1). Always consult the herbicide labels for specific rates and instructions. Apply the proper herbicides at the prescribed time and rate with a carefully calibrated applicator to provide the best return on your herbicide investment. Only chemicals that are cleared by the Environmental Protection Agency for the specific use intended should be used.

**No-Till or Minimum Till**

C6. In no-till or minimum till corn production, herbicides may be required to control or suppress emerged weeds. Glyphosate (Roundup) or paraquat (Gramoxone Super) are non-selective herbicides that will kill emerged weeds. These herbicides have no soil activity and are usually tank-mixed with other herbicides that provide residual control of later-germinating weeds (Table C1). **Paraquat is a restricted use herbicide.**

C7. Glyphosate (Roundup) is applied prior to corn emergence for annual and perennial weed control in reduced tillage situations. Two rate structures exist for annual weed control. With low-volume applications (3 to 10 gallons/A), a rate of 0.5 to 2 pt/A plus 0.5 to 1% v/v of a nonionic surfactant can be applied to actively growing weeds 6 inches or less in height. Do not tank mix with soil residual herbicides at these rates. With high volume application (10 to 40 gallons/A), a rate of 2 to 3 pt/A should be used. Use the 2 pt/A rate on weeds less than 6 inches tall. Perennial weeds may not be at the proper stage of growth for control. However, 4 to 8 pt/A may suppress emerged perennials. See the perennial weed control section for additional information.

C8. Paraquat will no longer be distributed by Chevron Chemical Company. ICI Americas, Inc. will be the sole distributor of paraquat. As a result, ICI's Gramoxone Super will be the only formulation of paraquat on the market; Chevron's Paraquat Plus will no longer be available. Gramoxone Super will have a 1.5 lb/gal formulation, replacing the 2 lb/gal formulation of last year and the color will be blue-green instead of brown.

C9. Atrazine and cyanazine (Bladex) may be used early preplant to control weed seedlings but are relatively ineffective on larger annual, biennial, and perennial weeds. The use of liquid nitrogen or fertilizer solutions as carriers in preplant or preemergence applications of atrazine and cyanazine improves its burndown effectiveness on larger, emerged weeds. If cyanazine is applied several weeks or more before corn planting, a post-planting herbicide treatment will be needed to provide adequate residual weed control.

**Preplant Incorporated Applications**

C10. Due to their volatility, butylate (Sutan+, Genate Plus) and EPTC (Eradicane, Eradicane Extra) must be immediately incorporated into the soil to ensure maximum weed control. Application and incorporation should be done in the same operation. If there must be a delay in incorporation (up to 4 hours is indicated on the label) these herbicides must be applied to a dry soil surface. Both butylate and EPTC volatilize (leave the soil) faster off of a moist or wet soil than a dry soil.

C11. Proper herbicide application and incorporation as well as favorable soil conditions are necessary for optimum herbicide performance. Ideally, the soil should be dry on the surface and moist, but not wet, just below the surface to ensure maximum mixing of the herbicide and soil. To provide good control, adequate moisture is needed at the point where the emerging weed seedling contacts the herbicide. Good incorporation thoroughly mixes the herbicide with 2 to 3 inches of soil. For best results, incorporate the herbicide twice with a disk, field cultivator with sweep shovels, or similar implement, or once with a power-driven rotary tiller. The second incorporation should be carried out at a right angle to the direction of the first incorporation to ensure thorough mixing of the herbicide with the soil. A one pass incorporation may be effective but is dependent upon the incorporation implement, soil type, moisture, and tilth, and plant residue cover. Read the label for more specific incorporation procedures.

C12. Butylate (Sutan+, Genate Plus) and EPTC (Eradicane, Eradicane Extra) applied preplant incorporated give good control of annual grass and some annual broadleaf weeds. Tank mixtures of atrazine and/or cyanazine (Bladex) with butylate or EPTC improves the broadleaf weed control. Cyanazine does not carryover to the next year and the lower rates of atrazine used in the mixtures reduces the carryover problems associated with the higher rates of atrazine. Both butylate and EPTC are effective on nutsedge. EPTC may be used for quackgrass control but results have been inconsistent. EPTC is the most effective soil-applied herbicide for wild proso millet and woolly cupgrass control. Following repeated annual use, the weed control effectiveness of butylate or EPTC may decline due to an increased rate of butylate or EPTC breakdown by soil microorganisms.

**Preplant Incorporated or Preemergence Applications**

C13. Several herbicides including alachlor (Lasso), atrazine, cyanazine (Bladex), and metolachlor (Dual) are suggested for use either preplant incorporated or preemergence. These herbicides may be left on the soil surface or incorporated with one or two tillage operations. Preplant incorporated applications of these herbicides into moist soil are more effective when there is inadequate rainfall to activate preemergence applications. However, preemergence applications provide more effective weed control when adequate rainfall does occur. If weed seedlings begin to emerge following a preemergence application, due to lack of rainfall, an early harrowing, rotary hoeing, or shallow cultivation will improve weed control.

C14. Alachlor (Lasso) and metolachlor (Dual) control annual grasses, nutsedge, redroot pigweed, and nightshade. Control of other broadleaf weeds has been erratic. However, atrazine or cyanazine may be tank mixed with either alachlor or metolachlor to improve broadleaf weed control. Preemergence applications of alachlor and metolachlor control nutsedge on coarse soils that are low in organic matter, but on fine-textured dark soils, preplanting incorporated applications give better control. Alachlor has been found to cause tumors in laboratory animals when fed to them over long periods of time. As a result, the EPA has proposed that alachlor be registered as a restricted use pesticide in 1988. The restricted use labeling will help to put this herbicide into the hands of more skilled and informed applicators.

C15. Atrazine at 1 to 3 lbs/A controls foxtails and many annual broadleaf weeds with no injury to corn. Use the high atrazine rate on fine-textured or high organic matter soils. Use the low rates of atrazine on low organic matter or sandy soils. Atrazine's effectiveness depends on moisture to move it into the root zone of weeds. Therefore, in western Minnesota, where rainfall is less certain, an early postemergence treatment of atrazine may be more effective. Atrazine residues can sometimes carryover and affect atrazine sensitive crops the next spring. Some of these atrazine sensitive crops includes the following: small grains, flax, sugarbeets, sunflowers, vegetables, soybeans, alfalfa, and other legumes. The label recommends that small grains, flax, sugarbeets, vegetables, and small-seeded legumes or grasses not be planted in the year following atrazine application. Atrazine tolerant crops may be safely planted; these crops are: corn, sorghum, sudangrass, and proso millet. Soybeans may be injured the year following atrazine use if the application rate of atrazine exceeded 2 lbs/A of active ingredient in western Minnesota or 3 lbs/A in eastern Minnesota. However, in some years, soybean injury has occurred following use within these restrictions, especially if one or more of the following occurred: soil moisture or soil temperatures were low or atrazine was applied on the highly alkaline soils prevalent in western Minnesota. Atrazine residue can be minimized by using the lowest rate consistent with good weed control, using band rather than broadcast applications, plowing the soil before planting the next rotational crop, and using labeled tank mixtures which reduce the amount of atrazine applied.

C16. Cyanazine (Bladex) controls several annual grasses and most annual broadleaf weeds (except pigweed) when applied preemergence. Although cyanazine is chemically similar to atrazine there is no soil residue the following season. The higher rates of cyanazine are required on fine-textured or high organic matter soils. Corn injury may occur on sandy soils or where maximum rates are used on heavier soils. **Cyanazine is a Restricted Use Pesticide.**

**Preemergence Applications**

C17. Dicamba (Banvel) may be applied preemergence for broadleaf weed control. Tank mixtures with alachlor (Lasso), atrazine, cyanazine (Bladex), metolachlor (Dual), or pendimethalin (Prowl) add annual grass control compared to dicamba alone. Dicamba should be applied preemergence only on medium or fine-textured soils with more than 2.5 percent organic matter. Do not incorporate prior to corn emergence. Harrowing or dragging before corn emergence may increase corn injury.

C18. Linuron (Lorox) may be applied preemergence primarily for annual broadleaf weed control. Do not use on sands, loamy sands, or soils with less than 1 percent organic matter. On soils above 4 percent organic matter broadleaf weed control will be reduced. Do not apply linuron over the top of emerged corn or severe injury may occur. A 1:1 ratio of active ingredient of an atrazine-linuron mixture has given weed control comparable to an equivalent rate of atrazine alone, on low organic matter soils. Tank mixtures of linuron with atrazine, alachlor (Lasso), or propachlor (Ramrod) reduce the potential for linuron injury to corn and improve the broadleaf weed control spectrum of these three herbicides. Incorporation reduces the effectiveness of linuron.

C19. Pendimethalin (Prowl) may be used preemergence only at .75 to 2 lbs/A of active ingredient or in mixtures at .75 to 1.5 lb/A of active ingredient for annual grass and some broadleaf weed control. However, in Minnestoa trials, preemergence applications of pendimethalin have been somewhat less effective on grasses but more effective on broadleaf weeds than alachlor (Lasso) or metolachlor (Dual). Tank mixtures with atrazine and/or cyanazine (Bladex), or dicamba (Banvel) provide a broader spectrum of weed control. Corn root injury and lodging have occurred from application of pendimethalin, especially on sandy soils. Corn injury may increase if the pendimethalin gets incorporated or moved into the row during cultivation. However, it is safe to use a rotary hoe, if one is necessary.

C20. Propachlor (Ramrod) applied preemergence gives good annual grass control when applied at 4 to 6 lbs/A, active ingredient. Propachlor does not control most annual broadleaf weeds but may be used in tank mixtures with atrazine or linuron (Lorox) to increase broadleaf weed control. Propachlor is a most consistent annual grass herbicide in limited rainfall situations, such as northwestern Minnesota.

**Early Postemergence**

C21. Atrazine and crop or vegetable oil applied to weeds less than 1.5 inches tall effectively controls most annual broadleaf and some annual grass weeds. It is important to apply atrazine and oil to small (less than 1.5 inch) weeds or weed control may not be adequate. Surfactants and wetting agents are less effective than any of the oil additives. An atrazine application may be made until corn is 30 inches tall. Drop nozzles should be used when corn exceeds 10 inches in height to keep the spray out of the corn whorls and to give better spray coverage on the weeds. Early postemergence applications are preferred to preemergence if the soil is higher in clay or organic matter or if applied in western Minnesota where rainfall is less certain. Corn injury has occurred when atrazine and oil are applied to corn growing under cold, wet conditions. Corn injury has also resulted from adding 2,4-D to the atrazine.

C22. Cyanazine (Bladex) applied to weeds less than 1.5 inches tall and before the 5th corn leaf is visible, effectively controls most annual broadleaf and grass weeds. Bladex generally gives better grass control but is weaker on pigweed than atrazine plus oil. **Do not use Bladex 4L postemergence**; only the 80 W and 90 DF formulations are cleared for postemergence application. Vegetable oils or surfactants may be added under dry conditions to improve weed control effectiveness, but these additives increase the potential for corn injury and have resulted in severe leaf kill, corn stunting, and stand reduction if heavy rains or dews and cool temperatures occur soon after application. Do not use petroleum-based crop oils because corn leaf kill, stunting and stand reductions are likely to occur. Do not use Bladex as a postemergence treatment with nitrogen solution fertilizers. Small corn, spike to 2-leaf stage, is less likely to be injured than larger corn, 3- to 4-leaf stage. Do not use cyanazine postemergence on corn grown for seed, popcorn, or sweet corn. Any rotational crop may be planted in the fall or spring following a cyanazine treatment. **Cyanazine is a restricted use herbicide.**

C23. Tridiphane (Tandem) in mixtures with atrazine plus oil or cyanazine (Bladex 80W or 90DF) may improve the control of annual grasses in the 1- to 3-leaf stage. Do not add a petroleum-based crop oil to the cyanazine tridiphane mixture. See the paragraph on postemergence cyanazine (C22) for other cyanazine restrictions. Tridiphane only enhances weed control; do not use tridiphane by itself.

C24. Bentazon (Basagran) may be applied postemergence to control most small annual broadleaf weeds, Canada thistle, and yellow nutsedge. Corn is tolerant to bentazon at all stages of growth but do not apply it when corn is stressed from adverse growing conditions. Weed control is dependent upon weed size. With most weeds, best results are obtained when bentazon is applied before the 2- to 6-leaf stage. See the label for details. Crop oil concentrate or crop oil may be mixed with bentazon or bentazon and atrazine to improve weed control. Do not mix bentazon with fertilizers. Thorough coverage of the weeds is necessary for adequate control.

C25. Bromoxynil (Torch 4EC, Buctril) controls most annual broadleaf weeds. Bromoxynil does not control grasses or perennial weeds. For best results, bromoxynil must be applied when broadleaf weeds have 2 to 4 leaves. Bromoxynil is a contact herbicide. Therefore, thorough coverage of the weeds is necessary. Use drop nozzles when the corn exceeds 8 inches in height or the crop may interfere with weed coverage. Corn tolerance is good but leaf burn may occur under conditions of high temperatures or humidity. Do not add a spray additive or liquid fertilizer to bromoxynil used alone or in tank mixtures as crop injury may occur. See the specific label information for bromoxynil use in tank mixtures.

C26. In the rush to get corn planted early, many growers may delay application of preemergence herbicides for so long that the corn crop has already emerged. The following preemergence herbicides can be applied to emerged corn without major injury and still give effective weed control: alachlor (Lasso) may be applied to corn that is less than 5 inches tall; alachlor or metolachlor may be applied in a tank mix with dicamba (Banvel) to corn that is less than 3 or 5 inches tall, respectively; alachlor or metolachlor may be applied in a tank mix with atrazine to corn that is less than 5 inches tall. This also includes the metolachlor or alachlor plus atrazine package mixtures (Bicep and Lasso + atrazine). Do not use a liquid fertilizer carrier if you are applying to emerged corn, due to the risk of crop injury. Alachlor and metolachlor applied alone will not give effective control of emerged weeds. Alachlor and metolachlor in the tank mixtures listed above will give effective control if the weeds are no more than the 2-leaf stage.

C27. Pendimethalin (Prowl) in mixtures with atrazine or cyanazine (Bladex 80 W or 90 DF) may be applied after corn emergence but before the 5th leaf is visible and when weeds are no more than 1 inch tall. These tank mixtures are effective against many annual grass and broadleaf weeds. The pendimethalin and cyanazine tank mixture used following a preplant incorporated application of EPTC greatly improved wild proso millet and woolly cupgrass control. However, corn leaf burn, stunting, and stand reductions are possible if cool, wet weather occurs soon after treatment. Applications to corn in the spike to 2-leaf stage are safer than later applications but weed control effectiveness is best if the weeds have emerged.

**Postemergence Applications**

C28. Dicamba (Banvel) controls many annual and perennial broadleaf weeds. However, dicamba is weak on nightshade and wild mustard and does not control grasses. Dicamba does control Canada thistle, wild sunflower, and smartweed better than 2,4-D with less injury to corn. Up to 1 pt/A (.5 lb/A) may be used on corn up to 5 inches tall. Apply 1/2 pt/A (.25 lb/A) before corn is 3 feet tall or until 15 days before tassel emergence, whichever occurs first. Do not use on corn grown for seed. The lower rate of dicamba will control most annual broadleaf weeds with less effect to corn than the higher rate. Do not use oils or other additives with dicamba. Late application of dicamba may result in corn injury. Crop safety is improved by using drop nozzles in corn over 8 inches tall. Read the label carefully to prevent corn injury.

C29. **Caution:** Soybeans and other broadleaf plants are very sensitive to dicamba. In recent years, there were many instances in which dicamba drift affected soybeans. Users of dicamba must take special precautions to avoid spray drift at the time of application or vapor drift for several days after application. Spray drift can be minimized by reducing sprayer pressure, increasing water volumes with larger nozzles, and using drop nozzles to keep the spray release as low as possible and still give weed coverage. Drift potential is greater with windy or high temperature conditions. Applications are not recommended at temperatures above 85°F. Reduce spray and vapor drift effects on soybeans by spraying corn early in the season when temperatures are lower and before soybeans have emerged, or when they are small. Do not graze or harvest for dairy feed prior to the milk stage of the grain if corn is treated with dicamba. Read the label carefully for details on reducing soybean injury due to dicamba.

C30. Tank mixtures of dicamba (Banvel) and atrazine or cyanazine (Bladex 80 W or 90 DF) are labeled for use on corn up to the 4-leaf stage. These mixtures give good broadleaf weed control but grass weed control is erratic. The dicamba and atrazine package mixture (Marksman) is also labeled for this use.

C31. 2,4-D controls most annual broadleaf weeds. However, 2,4-D is weak on smartweed and does not control grasses. Small weeds are easiest to control. If dry conditions or larger weeds are present the low volatile ester formulation is more effective than the amine. However, the amine formulation is less likely to volatilize and injure sensitive crops and is also less likely to injure corn. Apply 2,4-D broadcast when corn is in the 2- to 5-leaf stage or until corn is 8 inches tall. After corn exceeds the 8 inch height use drop nozzles to prevent corn injury by avoiding treatment of upper leaves and the whorl. Most corn injury from 2,4-D occurs when it is applied to rapidly elongating corn under hot (generally greater than 85°F) and humid conditions. Also, corn hybrids vary in their tolerance to 2,4-D. Do not tank mix crop oil or atrazine with 2,4-D as the potential for corn injury increases. Do not apply 2,4-D from tasseling to dough stage or poor kernel set may occur. After the dough stage 2,4-D can be applied at 0.5 to 1 lb/A but it is more beneficial to control weeds earlier.

Table C1. Summary of herbicides for use in corn.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **NO-TILL MINIMUM TILL** | | | |
| **atrazine** | 2 to 3 | Kills emerged weed seedlings and provides preemergence control of most annual broadleaf and some grass weeds. Use of nitrogen fertilizer solutions or herbicide carriers will improve burndown. | C9 |
| (Atrazine 80W) | (2.5 to 3.75 lbs) | | |
| (Atrazine 90DF) | (2.2 to 3.3 lbs) | | |
| (Atrazine 4L) | (4 to 6 pts) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 2 to 2.5 | Adds preemergence control of annual grasses. | |
| glyphosate (Roundup) | .75 to 3 | Improves burndown of emerged weeds. Use only before corn emergence. | C7 |
| metolachlor (Dual) (Bicep[1]) | 1.5 to 2.5 | Adds preemergence control of annual grasses. | |
| paraquat (Gramoxone Super) | .25 to 1 | Improves burndown of emerged weeds. Use only before corn emergence. | C8 |
| Mixtures listed on other labels | | | |
| dicamba (Banvel) | .25 to .5 | Adds additional broadleaf weed control. | |
| pendimethalin (Prowl) | .75 to 1.5 | Adds preemergence annual grass control. Apply after planting. Do not incorporate. | C19 |
| **cyanazine** | 1.25 to 4.75 | Kills emerged weed seedlings and provides preemergence control of most annual broadleaf and some grass weeds. Use of nitrogen fertilizer solutions as herbicide carriers will improve burndown. If applied more than 15 days before planting a preemergence herbicide will be needed. **Bladex is a restricted use herbicide.** | C9 |
| (Bladex 80W) | (1.5 to 6 lbs) | | |
| (Bladex 90DF) | (1.35 to 5.3 lbs) | | |
| (Bladex 4L) | (2.5 to 9.5 pts) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 2 to 2.5 | Adds preemergence control of annual grasses and pigweeds. | |
| atrazine (Conquest[2]) | .4 to 1.6 | Improves preemergence control of some broadleaf weeds. | |
| metolachlor (Dual) | 1.5 to 2 | Adds preemergence control of annual grasses and pigweeds. | |
| 2,4-D LV ester | 1 to 1.5 | Adds additional broadleaf weed control. | |
| Mixtures listed on other labels | | | |
| atrazine + alachlor | .4 to 1.6 + 2 to 2.5 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| atrazine + metolachlor | .4 to 1.6 + 1.25 to 2.5 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| dicamba (Banvel) | .25 to .5 | Adds additional broadleaf weed control. | |
| pendimethalin (Prowl) | .75 to 1.5 | Adds preemergence annual grass control. Apply after planting. Do not incorporate. | C19 |
| **glyphosate** | .19 to 3 | Apply prior to corn emergence. At lower rates, controls emerged annual grasses and broadleaf weeds. At higher rates, suppresses emerged perennial weeds. A nonselective translocated herbicide with no soil activity so commonly combined with residual herbicides. | C7 |
| (Roundup 3S) | (.5 to 8 pts) | | |

Table C1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtures | | | |
| alachlor (Lasso) (Bronco[3]) | 2 to 4 | Adds preemergence control of most annual grass and a few broadleaf weeds. | |
| alachlor + atrazine | 2 to 4 + 1 to 2 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| alachlor + cyanazine (Bladex) | 2 to 4 + 1 to 2.2 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| dicamba (Banvel) | .25 to .50 | Adds additional broadleaf weed control. | |
| 2,4-D amine | .5 | Adds additional broadleaf weed control. | |
| Mixtures listed on other labels | | | |
| atrazine | 2 to 3 | Adds preemergence control of most annual broadleaf and a few grass weeds. | |
| atrazine + metolachlor (Dual) (Bicep[1]) | 1.2 to 2 + 1.5 to 2.5 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| metolachlor (Dual) | 1.5 to 2.5 | Adds preemergence control of most annual grass and a few broadleaf weeds. | |
| metolachlor + cyanazine (Bladex) | 1.5 to 2.5 + 1 to 2.2 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| Package mixture | | | |
| glyphosate + alachlor (Bronco 4L) | 3 to 5 | Bronco contains 1.4 and 2.6 lb/gal of glyphosate and alachlor, respectively. | |
| **paraquat** (Gramoxone Super 1.5 S) | .25 to 1 (1.3 to 5.3 pts) | Apply prior to corn emergence. Controls emerged annual grass and broadleaf weeds. A nonselective contact herbicide with no soil activity so commonly combined with residual herbicides. Apply with a .5 to 1 pt nonionic surfactant per 100 gal of spray solution. **A restricted use herbicide.** | C8 |
| Labeled mixtures | | | |
| atrazine | 2 to 3 | Adds preemergence control of most annual broadleaf and a few grass weeds. | |
| atrazine + alachlor (Lasso) | 1 to 2 + 2 to 3 | Adds preemergence control of most annual broadleaf and grass weeds. | |
| atrazine + metolachlor (Dual) (Bicep[1]) | 1.2 to 2 + 1.5 to 2.5 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| cyanazine (Bladex) | 1.2 to 4 | Adds preemergence control of most annual broadleaf and many grass weeds | |
| cyanazine + metolachlor | 1 to 2.2 + 1.5 to 2.5 | Adds preemergence control of most annual grass and broadleaf weeds. | |
| Mixture listed on other labels | | | |
| dicamba (Banvel) | .25 to .5 | Adds additional broadleaf weed control. | |
| **PREPLANT INCORPORATED** | | | |
| **butylate + safener** (Sutan+, Genate Plus 6.7 EC) | 3 to 6 (3.75 to 7.33 pts) | Controls many annual grass and some broadleaf weeds and yellow nutsedge. Incorporate immediately. Safeners have been added to protect corn from butylate injury. Repeated annual use may reduce weed control effectiveness. | C10, C11, C12 |

Table C1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtures | | | |
| atrazine | .75 to 1.5 | Adds broadleaf weed control. | |
| cyanazine (Bladex) | 1.5 to 2 | Adds broadleaf weed control. | |
| atrazine + cyanazine | .5 to 1 + 1 to 2 | Adds broadleaf weed control with less risk of atrazine carryover. | C15 |
| Package mixtures | | | |
| butylate + atrazine | | | |
| (Sutazine 6 ME) | 3.9 to 7.9 | Sutazine contains 4.8 and 1.2 lb/gal of butylate and atrazine, respectively. | |
| (Rhino 6F) | 4.5 to 8.8 | Rhino contains 4.3 and 1.7 lb/gal of butylate and atrazine, respectively. | |
| **EPTC + safener**<br>(Eradicane 6.7 EC)<br>(Eradicane Extra 6 EC) | 3 to 6<br>(3.75 to 7.33 pts)<br>(4 to 8 pts) | Controls many annual grass and some broadleaf weeds and yellow nutsedge. Incorporate immediately. Eradicane contains a safener to protect corn from EPTC injury. Eradicane Extra contains a safener plus an extender which increases the soil life of EPTC. Repeated annual use reduces weed control effectiveness. | C10, C11, C12 |
| Labeled mixtures | | | |
| atrazine | 1 to 1.5 | Adds broadleaf weed control. | |
| cyanazine (Bladex) | 1.5 to 2 | Adds broadleaf weed control. | |
| atrazine + cyanazine | .5 to 1 + 1 to 2 | Adds broadleaf weed control with less risk of atrazine carryover. | C15 |
| **PREPLANT OR PREEMERGENCE** | | | |
| **alachlor**<br>(Lasso 4 EC)<br>(Lasso II) | 1.5 to 4<br>(3 to 8 pts)<br>(16 to 26 lbs) | Controls annual grass and some broadleaf weeds including nightshade. Weak on wild mustard. Labeled postemergence on corn up to 5 inches tall but less effective on emerged weeds. Alachlor will probably be a restricted use herbicide in 1988. | C13, C14, C26 |
| Labeled mixtures | | | |
| atrazine | 1 to 1.85 | Adds broadleaf weed control. Can apply to corn up to 5 inches tall. | C26 |
| cyanazine (Bladex) | 1 to 2.4 | Adds broadleaf weed control. | |
| dicamba (Banvel) | .5 | Adds broadleaf weed control. Do not incorporate. Can apply to corn up to 3 inches tall. | C17, C26 |
| atrazine + cyanazine | .75 to 1.25 + 1 to 2 | Adds broadleaf weed control with less risk of atrazine carryover. | C15 |
| Package mixtures | | | |
| alachlor + atrazine<br>(Lasso + atrazine 4F) | 2.5 to 5 | Lasso plus atrazine contains 2.5 and 1.5 lb/gal of alachlor and atrazine, respectively. | |
| **atrazine**<br>(Atrazine 80W)<br>(Atrazine 90DF)<br>(Atrazine 4L) | 2 to 4<br>(2.5 to 5 lbs)<br>(2.2 to 4.4 lbs)<br>(4 to 8 pts) | Controls many broadleaf and some grass weeds. Use split application for quackgrass (see the perennials section). May carryover and injure sensitive crops. See reference C15 for details. | C13, C15 |

Table C1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtures | | | |
| alachlor (Lasso) | 2 to 3 | Adds annual grass weed control. | |
| butylate (Sutan+, Genate Plus) | 4 to 6 | Adds annual grass weed control. Must be incorporated. | |
| cyanazine (Bladex) | .75 to 3.75 | Improves annual grass weed control with less risk of atrazine carryover. | C15 |
| metolachlor (Dual) | 1.5 to 2.5 | Adds annual grass weed control. | |
| pendimethalin (Prowl) | .75 to 1.5 | Improves annual grass weed control. Do not incorporate. | C19 |
| propachlor (Ramrod) | 4 to 6 | Adds annual grass weed control. Do not incorporate. | |
| **cyanazine** | .6 to 4.75 | Controls many annual broadleaf and grass weeds. Weak on pigweeds. | C13, C16 |
| (Bladex 80W) | (.75 to 5.9 lbs) | No carryover problem but corn injury possible on sandy soils. | |
| (Bladex 90DF) | (.67 to 5.3 lbs) | **Bladex is a restricted use herbicide.** | |
| (Bladex 4L) | (1.2 to 9.5 pts) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 2 to 2.5 | Improves annual grass and pigweed control. | |
| atrazine | .4 to 1.6 | Improves pigweed control. | |
| butylate (Sutan+, Genate Plus) | 3 to 4 | Improves annual grass weed control. Must be incorporated. | |
| EPTC (Eradicane, Eradicane Extra) | 3 to 4 | Improves annual grass weed control. Must be incorporated. | |
| metolachlor (Dual) | 1.25 to 2.5 | Improves annual grass and pigweed control. | |
| pendimethalin (Prowl) | .75 to 1.5 | Improves annual grass control. Do not incorporate. | C19 |
| Package mixture | | | |
| cyanazine + atrazine (Conquest 4F) | .6 to 5.25 | Conquest contains 2.98 and 1.02 lb/gal of cyanazine and atrazine, respectively. | |
| **dicamba** | .25 to .50 | Controls many broadleaf weeds. Apply preemergence only on medium- or fine-textured soils with more than 2.5 percent organic matter. Do not incorporate prior to corn emergence. The high rate of dicamba can be used until corn exceeds 5 inches in height. | C17 |
| (Banvel 4S) | (.5 to 1 pt) | | |
| (Banvel II 2S) | (1 to 2 pts) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 1.5 to 4 | Adds annual grass control. Can apply to corn up to 3 inches tall. Apply only to fine-textured soils with more than 3 percent organic matter. | C26 |
| atrazine | 1.25 to 4 | Improves broadleaf and adds some grass weed control. Application may be made until grasses exceed 1.5 inches in height. | |
| cyanazine (Bladex) | 1.25 to 4 | Improves broadleaf and adds some grass weed control. Application may be made until grasses exceed 1.5 inches in height or corn exceeds the 4-leaf stage. | |
| metolachlor (Dual) | 1.5 to 3 | Adds annual grass control. Apply before weeds and corn emerge. | |
| pendimethalin (Prowl) | 1 to 1.5 | Adds some grass weed control. Apply before weeds and corn emerge. | C19 |

Table C1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| <u>Package mixtures</u> | | | |
| dicamba + atrazine (Marksman 3.2 F) | .8 to 1.4 | Marksman contains 1.1 and 2.1 lb/gal of dicamba and atrazine, respectively. Application may be made through the fifth-leaf stage of corn. | |
| **linuron** | .33 to 1.5 | Controls many annual broadleaf weeds. Apply preemergence in tank mixtures. Corn injury is likely when applied to sand or loamy soils or soils with less than 1 percent organic matter. Linuron plus a surfactant may be applied directed-postemergence to corn over 15 inches tall and weeds up to 5 inches tall. Linuron will kill corn leaves it contacts. | C18 |
| (Lorox 50 WP) | (.67 to 3 lbs) | | |
| (Lorox 50 DF) | (.67 to 3 lbs) | | |
| (Lorox 4F) | (.67 to 3 pts) | | |
| <u>Labeled mixtures</u> | | | |
| alachlor (Lasso) | .75 to 2.5 | Adds annual grass weed control. | |
| atrazine | .4 to 1.6 | Improves broadleaf weed control and adds some annual grass weed control. | |
| propachlor (Ramrod) | 1.3 to 6 | Adds annual grass weed control. | C20 |
| **metolachlor** | 1.5 to 3 | Controls annual grass and some broadleaf weeds. Can be applied early preplant, either alone or in tank mixtures for weed control in minimum- or no-till corn. In tank mixtures with atrazine or Banvel, another 1.5 to 3 pts/A of metolachlor can be applied to corn less than 5 inches tall. | C13, C14, C26 |
| (Dual 8E) | (1.5 to 3 pts) | | |
| (Dual 25G) | (6 to 12 lbs) | | |
| <u>Labeled mixtures</u> | | | |
| atrazine | 1 to 2 | Improves annual broadleaf weed control. | C26 |
| cyanazine (Bladex) | .8 to 2.5 | Improves annual broadleaf weed control. | |
| dicamba (Banvel) | .5 | Improves annual broadleaf weed control. Preemergence only. | C17, C26 |
| linuron (Lorox) | .3 to .5 | Improves annual broadleaf weed control. Preemergence only. | C18 |
| <u>Package mixture</u> | | | |
| metolachlor + atrazine (Bicep 6F) | 2.25 to 4.5 | Bicep contains 3.3 and 2.7 lb/gal of metolachlor and atrazine, respectively. Application may be made to corn 5 inches or less. | C26 |
| **propachlor** | 4 to 6 | Controls many annual grass weeds. Apply preemergence only. Propachlor gives consistent annual grass control in limited rainfall areas. | C20 |
| (Ramrod 4F) | (8 to 12 pts) | | |
| (Ramrod 20 G) | (20 to 30 lbs) | | |
| <u>Labeled mixture</u> | | | |
| atrazine | 1 to 1.6 | Adds annual broadleaf weed control. | |
| <u>Package mixture</u> | | | |
| propachlor + atrazine (Ramrod + atrazine 4F) | 3.5 to 5.5 | Ramrod plus atrazine contains 3 and 1 lb/gal of propachlor and atrazine, respectively. | |

Table C1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
| --- | --- | --- | --- |
| **POSTEMERGENCE** | | | |
| **atrazine with oil** | 1 to 2 | Controls many broadleaf weeds up to 4 inches tall and some grasses up to 1.5 inches tall. See reference and label for more details. If weed control is poor, cultivation will be required. | C21 |
| (Atrazine 80W) | (1.25 to 2.5 lbs) | | |
| (Atrazine 90DF) | (1.1 to 2.2 lbs) | | |
| (Atrazine 4L) | (2 to 4 pts) | | |
| Labeled mixtures | | | |
| pendimethalin (Prowl) | .75 to 1.5 | Improves grass control. Apply to corn in the spike to 4-leaf stage. Do not add oil. | C27 |
| tridiphane (Tandem) | .5 to .75 | May improve control of annual grasses in the 1- to 3-leaf stage of development. | C23 |
| **bentazon** | .75 to 1 | Controls small annual broadleaf weeds, Canada thistle, and yellow nutsedge. A second application may be required for Canada thistle and yellow nutsedge. Thorough coverage of the weeds is essential. | C24 |
| (Basagran 4S) | (1.5 to 2 pts) | | |
| Labeled mixture | | | |
| atrazine | .5 to .75 | Improves broadleaf weed control. Always add oil concentrate. | |
| Package mixture | | | |
| bentazon + atrazine (Laddok 3.3 F) | 1 to 1.5 | Laddok contains 1.66 and 1.66 lb/gal of bentazon and atrazine, respectively. | |
| **bromoxynil** | .25 to .5 | Controls most annual broadleaf weeds. For best results apply to 2- to 4-leaf weeds. Bromoxynil is a contact herbicide; therefore, thorough weed coverage is essential. | C25 |
| (Torch 4EC) | (.5 to 1 pt) | | |
| (Buctril 2EC) | (1 to 2 pts) | | |
| Labeled mixtures | | | |
| atrazine | .5 to 1.2 | Improves pigweed control and may improve control of some larger broadleaf weeds. Do not use oil. | |
| dicamba | .25 | Improves pigweed and perennial broadleaf weed control. Avoid drift to sensitive crops. | C29 |
| 2,4-D | .25 | Improves pigweed and perennial broadleaf weed control. | |
| Package mixtures | | | |
| bromoxynil + atrazine | | | |
| (Torch Twin Pack) | .58 to .88 | Torch twin pack consists of two containers with 1.9 and 2.5 gallons of Brominal and atrazine, respectively. | |
| (Buctril + Atrazine) | .56 to 1.12 | Buctril plus atrazine contains 1 and 2 lbs/gal of bromoxynil and atrazine, respectively. | |

Table C1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **cyanazine** | 1.2 to 2 | Controls small annual broadleaf and grass weeds. Weak on pigweed. Do not spray if 5th corn leaf is visible. **Do not use Bladex 4L.** Under dry conditions add surfactant or vegetable oil. **Bladex is a restricted use herbicide.** | C22 |
| (Bladex 80W) | (1.5 to 2.5 lbs) | | |
| (Bladex 90DF) | (1.35 to 2.2 lbs) | | |
| Labeled mixtures | | | |
| atrazine | .4 to 6 | Improves pigweed control. | |
| dicamba (Banvel) | .25 to .33 | Improves pigweed control. Avoid drift to sensitive crops. | C29 |
| pendimethalin (Prowl) | .75 to 1.5 | Improves wild proso millet and woolly cupgrass control. Apply to small corn for least amount of corn injury. | C27 |
| tridiphane (Tandem) | .5 to .75 | May improve control of annual grasses in the 1- to 3-leaf stage of development. | C23 |
| **dicamba** | .25 to .5 | Controls many annual and perennial broadleaf weeds. No grass control. Use up to .5 lb/A on corn less than 5 inches tall; use up to .25 lb/A on corn less than 3 feet tall. Use drop nozzles in corn over 10 inches tall. Avoid drift to sensitive species. | |
| (Banvel 4S) | (.5 to 1 pts) | | C28, C29 |
| (Banvel II 2S) | (1 to 2 pts) | | C30 |
| Labeled mixtures | | | |
| alachlor (Lasso) | 1.5 to 4 | Apply to corn less than 3 inches tall. Provides annual grass control. | |
| atrazine | 1.25 to 4 | Apply before grasses are 1.5 inches tall. Provides some annual grass control. | C30 |
| cyanazine (Bladex 80W) | 1.25 to 4 | Apply to corn before the 5th leaf is visible and before the grasses are 1.5 inches tall. Provides some annual grass control. | C30 |
| 2,4-D | .12 to .25 | Improves wild mustard control. Use drop nozzles after corn is 8 inches tall. | |
| Package mixture | | | |
| dicamba + atrazine (Marksman 3.2F) | .8 to 1.4 | Marksman contains 1.1 and 2.1 lb/gal of dicamba and atrazine, respectively. Application may be made through the fifth-leaf stage of corn. | |
| **2,4-D** | .25 to 1 | Controls emerged annual and perennial broadleaf weeds. Use drop nozzles after corn is 8 inches tall. Do not spray from before tasseling until the silks are brown. Corn stalk brittleness commonly occurs when the corn stalk is elongating. Higher 2,4-D rates, .5 to 1 lb/A, may be used after the hard dough stage to control perennials and large annuals. Avoid spray drift to soybeans or other sensitive crops. | C31 |
| (amine 4L) | (.5 to 2 pts) | | |
| (ester 4L) | (.5 to 2 pts) | | |

*Reference paragraph number indicates appropriate paragraph in the narrative.

[1]Package mixture of 3.3 and 2.7 lb/gal of metolachlor and atrazine, respectively.

[2]Package mixture of 2.98 and 1.02 lb/gal of cyanazine and atrazine, respectively.

[3]Package mixture of 1.4 and 2.6 lb/gal of glyphosate and alachlor, respectively.

Table C2. Effectiveness of herbicides on major weeds in corn[1,2]

| | | Grasses | | | | | | | | | | Broadleafs | | | | | | | | | | | Perennials | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Corn tolerance | Barnyardgrass | Crabgrass | Wooly cupgrass | Giant and robust foxtail | Green foxtail | Yellow foxtail | Wild proso millet | Wild oats | Fall panicum | Sandbur | Buffalobur | Cocklebur | Kochia | Lambsquarters | Mustard | Eastern black nightshade | Pigweed | Ragweed | Smartweed | Wild sunflower | Velvetleaf | American germander | Canada thistle | Jerusalem artichoke | Nutsedge | Quackgrass |
| **Preplant incorporated** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| alachlor (Lasso) | G | G | G | G | G | G | G | F | P | G | F | P | P | P | F/P | P | F | G | P | P | P | P | N | N | N | G | N |
| atrazine (AAtrex, others) | G | F | P | P | F | G | G | P | G | P | F | P | F | G | G | G | G | G | G | G | F | F | P | P | P | P | G* |
| butylate (Sutan+, Genate Plus) | G | G | G | F | G | G | G | F | F | G | G | F | P | P | P | P | F | F | P | P | P | F | P | N | N | G | N |
| cyanazine (Bladex) | F | F | F/G | P | F/G | G | G | P/F | F | F | F | P | F | G | G | G | G | F | G | G | F | F | P | P | P | P | P |
| EPTC (Eradicane, Eradicane Extra) | G | G | G | G | G | G | G | F/G | F | G | G | G | P | F | F/G | P | F | F | F | P | P | F | F | N | N | G | F |
| metolachlor (Dual) | G | G | G | G | G | G | G | F | P | G | F | P | N | P | F/G | P | F | G | P | P | P | P | N | N | N | G | N |
| **Preemergence** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| alachlor (Lasso) | G | G | G | G | G | G | G | F | P | G | F | P | N | P | F/P | P | G | G | P | P | P | P | N | N | N | F | N |
| atrazine (AAtrex, others) | G | F | P | P | F | G | G | P | G | P | F | P | F | G | G | G | G | G | G | G | F | F | P | P | P | P | G* |
| cyanazine (Bladex) | F | F | F/G | P | F/G | G | G | P/F | F | F | F | P | F | G | G | G | G | F | G | G | F | F | P | P | P | P | P |
| dicamba (Banvel) | F | P | P | P | P | P | P | P | N | P | P | P | F | F | G | G | F | G | G | G | F | F | P | N | P | N | N |
| linuron (Lorox) | F | F | F | P | F | F | F | P | P | F | P | P | F | F | G | G | P | G | G | G | F | F | P | N | P | P | N |
| metolachlor (Dual) | G | G | G | G | G | G | G | F | P | G | F | P | N | P | F/P | P | G | G | P | P | P | P | N | N | N | F | N |
| propachlor (Ramrod) | G | F | G | F | G | G | G | F | P | F | P | P | P | P | P | P | P | F | P | P | P | P | N | N | N | F | N |
| **Postemergence** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| atrazine & oil (AAtrex, others) | G | F | P | F | F | G | G | P | G | P | F/G | G | G | G | G | G | G | G | G | G | G | F | G | F | P | F | G* |
| bentazon (Basagran) | G | N | N | N | N | N | N | N | N | N | P | P | G | - | F | G | P | P | G | G | G | G | P | F/G* | P | G* | N |
| bromoxynil (Buctril, Torch) | G | N | N | N | N | N | N | N | N | N | N | G | G | G | G | G | G | G | G | G | G | G | N | F | N | N | N |
| cyanazine (Bladex) | F | F | F | F | F | G | G | P/F | F | F | F | F | F | G | G | G | G | F | G | G | F | F | F | P | P | P | P |
| dicamba (Banvel) | G | N | N | N | N | N | N | N | N | N | P | P | G | G | G | F | F | G | G | G | G | G | P | G | G | N | N |
| pendimethalin + atrazine (Prowl + atrazine) | F/G | G | F/G | F | G | G | G | F | G | F/G | F | G | G | G | G | G | G | G | G | G | G | G | F | P | P | P | P |
| pendimethalin + cyanazine (Prowl + Bladex) | F | G | G | G | G | G | G | G | G | G | F/G | F | F | G | G | G | G | F | G | G | G | G | F | P | P | P | P |
| 2,4-D | F | N | N | N | N | N | N | N | N | N | P | P | G | F | G | G | F | G | G | P | F | G | P | F | G | N | N |

[1]G = Good; F = Fair; P = Poor; N = None; - = insufficient information.

[2]This chart should be used only as a guide. Ratings of chemicals may be higher or lower than indicated depending on soil characteristics, managerial factors, environmental variables, and rates applied.

*Degree of perennial weed control is often a result of repeated application.

## DRY EDIBLE BEANS

DB1. Dry beans are sensitive to weed competition. Early weed growth reduces bean yields by competing for light, moisture, and nutrients. Weeds also are likely to cause a buildup of disease and/or insect problems that may adversely affect bean growth and development adversely. Weeds increase harvest losses and reduce bean quality. Cultivation or other tillage sometimes controls weeds adequately without the use of herbicides. However, weeds usually are not controlled adequately in the row. There, the use of herbicides and tillage is often necessary.

### Early Growth and Development of Beans

DB2. Dry beans grown in Minnesota include five common bean (Phaseolus sp.) classes: navy, pinto, kidney, pink, and small red, as well as the adzuki bean (Vigna sp.). All common beans emerge by elongation of the hypocotyl (portion of the stem below the cotyledons or seed leaves), which "crooks" or arches through the soil and then straightens out with unfolding cotyledons. These common beans emerge quite rapidly (usually within 7-10 days) if planted in warm soil (50°F or higher) in late May or early June in Minnesota. However, earlier planting may delay emergence. Adzuki beans, on the other hand, emerge by elongation of the epicotyl (portion of the stem above the cotyledons), and the cotyledons (seeds) remain below the soil surface. Adzuki beans emerge more slowly than common beans, usually 10-14 days in warm soils and 15-20 days in cold soils. Because of the type and time required for emergence, weed control in adzuki beans is more critical and they are more susceptible to injury from preplanting or preemergence herbicides. For example, EPTC (Eptam or Genep), alachlor (Lasso) and metolachlor (Dual) can be used on common beans but should not be used on adzuki beans.

### Cultural Practices

DB3. Before emergence, dry beans can be spike-toothed harrowed to kill emerging weeds. The rotary hoe or flexible-tined harrow are safer to use after bean emergence than the spike-toothed harrow. More than one harrowing may be necessary. After the beans emerge, they develop quite rapidly and progress through the cotyledon stage (or plumule stage in the adzuki bean) to the fully expanded unifoliolate leaf stage and then to the first and subsequent trifoliolate (three-part) leaves. Beans differ in canopy growth. Most navy and adzuki bean varieties are erect or "bush" type. Most pinto, pink, and small red bean varieties are prostrate vines, although bush or semi-vine types of small red and pinto are available. Dry edible beans may be cultivated once or twice to control weeds; however, cultivation should be shallow to avoid damaging the rather shallow root systems. Do not cultivate or harrow when the bean foliage is wet because bacterial diseases may be spread. Beans are hilled at the last cultivation to allow use of bean pullers. However, if beans are to be direct-combined or swathed, the last cultivation should leave the field as level as possible.

## Herbicides

DB4. Alachlor (Lasso), EPTC (Eptam/Genep), ethalfuralin (Sonalan), metolachlor (Dual), pendimethalin (Prowl), and trifluralin (Treflan) can be applied preplant incorporated for annual grass and some broadleaf weed control. Wild oat control is not adequate with any of these herbicides. Rates are dependent on soil type. Do not use alachlor (Lasso), EPTC (Eptam/Genep), metolachlor (Dual), or pendimethalin (Prowl) on adzuki beans.

DB5. Alachlor (Lasso), ethalfluralin (Sonalan), metolachlor (Dual), and chloramben (Amiben) will give early season control of eastern black and hairy nightshade. Use the highest rate of ethalfluralin.

DB6. Chloramben (Amiben) applied preemergence or preplant incorporated will control annual grasses and some broadleaf weeds. Wild oat control is not adequate. If adequate rainfall does not occur after application and weeds start to emerge, a shallow incorporation will result in more consistent weed control. Use the lower rate on adzuki beans. Chloramben can be applied preplant incorporated with EPTC (Eptam/Genep), alachlor (Lasso), metolachlor (Dual), and trifluralin (Treflan) or as an overlay treatment to these herbicides applied preplant incorporated.

DB7. Bentazon (Basagran) applied postemergence will control many annual broadleaf weeds and will suppress Canada thistle. Apply before annual weeds are 6 inches tall. Use the lower rate on adzuki beans. Addition of crop oil may cause bean injury.

## Summary

DB8. A weed control program in dry beans should be based on the kind of beans, the weed species in the field, soil type, type of tillage and whether or not irrigation is available. Herbicide costs and expected bean yields should be considered. If perennial or other weeds that cannot be controlled by tillage or a labeled herbicide are present, a more competitive crop than dry beans should be planted. Adequate weed control, especially for the first three to four weeks, is necessary for profitable dry bean production.

Table DB1. Summary of herbicides for use on dry beans.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **Preplant incorporated and/or Preemergence** | | | |
| **alachlor** | 2.5 to 3 | Apply preplant incorporated. Do not use on adzuki beans. | DB4, DB5 |
| (Lasso) | (2.5 to 3 qts) | | |
| **chloramben** | 2 to 3 | Apply preemergence or preplant incorporated. Use lower rate on adzuki beans. | DB5, DB6 |
| (Amiben) | (4 to 6 qts) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 1.5 to 2.5 | Apply preplant incorporated. Rate dependent on soil type. Do not use on adzuki beans. | |
| EPTC (Eptam/Genep) | 2.2 to 3 | Apply preplant incorporated. Do not use on adzuki beans. | |
| metolachlor (Dual) | 1.5 to 2.5 | Apply preplant incorporated. Rate dependent on soil type. Do not use on adzuki beans. | |
| trifluralin (Treflan) | 0.75 to 1 | Apply preplant incorporated. Rate dependent on soil type. | |
| **EPTC** | 4 to 4.6 | Apply preplant incorporated in the fall. Do not use on adzuki beans. | |
| (Eptam/Genep) | (4.5 to 5.25 pts) | | |
| | 3 to 4 | Apply preplant in the spring. Do not use on adzuki beans. | |
| | (3.5 to 4.5 pts) | | |
| **ethalfluralin** | .56 to 1.69 | Apply preplant incorporated. Use higher rate for nightshade control. Adzuki bean tolerance unknown. | DB4, DB5 |
| (Sonalan) | (1.5 to 4.5 pts) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 1.25 to 2 | Apply preplant incorporated. | |
| chloramben (Amiben) | 2 to 3 | Apply preplant incorporated or as an overlay treatment. | |
| EPTC (Eptam/Genep) | 3 | Apply preplant incorporated. Do not use on adzuki beans. | |
| metolachlor (Dual) | 1.5 to 3 | Apply preplant incorporated. Rate dependent on soil type. Do not use on adzuki beans. | |
| **metolachlor** | 1.5 to 3 | Apply preplant incorporated or preemergence. Rate dependent on soil type. Do not use on adzuki beans. | DB4, DB5 |
| (Dual) | (1.5 to 3pts) | | |
| Labeled mixtures | | | |
| chloramben (Amiben) | 2 to 3 | Apply preplant incorporated or preemergence. | |
| EPTC (Eptam/Genep) | 3 to 4 | Apply preplant incorporated. | |
| trifluralin (Treflan) | 0.75 to 1 | Apply preplant incorporated. | |
| **pendimethalin** | 0.5 to 1.5 | Apply preplant incorporated. Do not use on adzuki beans. | DB4 |
| (Prowl) | (1 to 3 pts) | | |
| Labeled mixture | | | |
| EPTC (Eptam/Genep) | 2.2 + 4 | Apply preplant incorporated. Do not use on adzuki beans. | |

Table DB1. Summary of herbicides for use on dry beans, continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **trifluralin** (Treflan) | 0.50 + 1 (1 to 2) | Apply preplant incorporated. Rate dependent on soil type. | DB4 |
| Labeled mixture | | | |
| EPTC (Eptam/Genep) | 2.2 to 4 | Apply preplant incorporated. Rate dependent on soil type. Do not use on adzuki beans. | DB4 |
| **Postemergence** | | | |
| **bentazon** (Basagran) | .75 to 1 | Apply after beans are in the first trifoliolate stage and weeds are small. Use lower rate on adzuki beans. Addition of crop oil may cause bean injury. | DB7 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

**Table DB2. Effectiveness of herbicides on major weeds in dry beans.**

| | | | Grasses | | | | Broadleafs | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Herbicides** | **Type of application** | **Dry bean tolerance (not adzuki)** | **Green & yellow foxtail** | **Wild oats** | **Canada thistle** | **Cocklebur** | **Common lambsquarters** | **Common ragweed** | **Eastern black nightshade** | **Hairy nightshade** | **Kochia** | **Pigweed spp.** | **Smartweeds** | **Wild mustard** |
| alachlor (Lasso) . . . . . . . . . . | PPI | G | G | P | N | P | F | P | G | G | P | G | P | P |
| bentazon (Basagran). . . . . . . . . | POST | G | N | N | G | G | P | G | F | F | P | P | G | G |
| chloramben (Amiben). . . . . . . . . | PRE/ PPI | G | G | P | N | P | G | G | G | G | F | G | G | F |
| EPTC (Eptam/Genep) . . . . . . . . . | PPI | G | G | F | N | P | F | F | P | P | F | F | P | P |
| ethalfluralin (Sonalan). . . . . . . | PPI | G | G | F | N | N | F | N | F | F | G | G | P | N |
| metolachlor (Dual) . . . . . . . . . | PRE/ PPI | G | G | P | N | P | F | P | G | F | P | G | P | P |
| pendimethalin (Prowl). . . . . . . . | PPI | G | G | P | N | N | F | N | P | P | G | G | F | N |
| trifluralin (Treflan). . . . . . . . | PPI | G | G | P | N | N | F | N | P | P | G | G | P | N |

G = Good, F = Fair, P = Poor, N = None
PRE = Preemergence, PPI = Preplant incorporated, POST = Postemergence

## FLAX

### Cultural Practices

F1. Flax is not a strong competitor with weeds, so weed control is essential in obtaining high flax yields. Shallow early spring tillage to stimulate germination of annual weeds, followed by tillage operations to kill these weeds has been a successful method of weed control. However, using this method of weed control results in delayed seeding of flax which usually decreases yield. Therefore, appropriate preplanting and postharvest tillage, together with suitable chemical weed control should be used for best results.

### Herbicides

F2. Flax is a poor competitor with weeds so control is needed before or soon after emergence to reduce field yield losses. Preemergence herbicides control weeds before emergence and eliminate early weed competition. Apply postemergence herbicide treatments as soon as possible.

F3. Bromoxynil (Brominal ME4, Buctril) can be used to control many annual broadleaf weeds. Apply Brominal ME4 at 0.25 to 0.50 lb/A (.5 to 1 pt) when flax is 2 to 8 inches tall. Apply Buctril at 0.25 lb/A (1 pt) when flax is 2 to 4 inches tall. Do not apply bromoxynil in humid weather. Temperatures at the time of treatment, or for three days after treatment, must be below 85° F to avoid flax injury.

F4. Dalapon (Dowpon) will control small (less than 2 inches) foxtail but not wild oats. Apply dalapon to flax that is from 1 to 6 inches tall. Dalapon can be tank mixed with MCPA amine for broadleaf weed control. Dalapon may injure flax, especially under drought conditions.

F5. Diclofop (Hoelon) will control annual grasses, including wild oats. Apply when grassy weeds are in the 1 to 4 leaf stage. Do not add crop oil concentrate. Diclofop can be tank mixed with bromoxynil (Brominal ME4, Buctril) for broadleaf weed control.

F6. EPTC (Eptam/Genep) can be applied preplant incorporated only in the fall. Rate is dependent on soil type. Flax tolerance to EPTC is marginal, therefore, flax injury is possible. Do not apply in the spring.

F7. Trifluralin (Treflan) can be applied preplant incorporated only in the fall. Trifluralin will control annual grasses, except wild oats, and some broadleaf weeds. Flax tolerance is marginal.

F8. Propachlor may be applied preemergence to control annual grasses except wild oats. Propachlor will also control kochia and pigweed. Do not incorporate because of flax injury. Adequate rainfall after application is needed for effective weed control. Flax tolerance is good.

F9. MCPA (amine or esters) will control most annual broadleaf weeds. However, MCPA is weak on wild buckwheat and smartweeds. Apply when flax is 2 to 6 inches tall. Flax tolerance is marginal especially at higher rates.

Table F1. Summary of herbicides for use on flax.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **Preemergence or Preplant Incorporated** | | | |
| **EPTC** (Eptam/Genep) | 4 to 4.5 (4.5 to 5.25 pt) | Apply preplant incorporated in the fall after October 15 until freeze-up. Some flax injury may occur. Rate dependent on soil type. | F6 |
| **trifluralin** (Treflan TR-10) (Treflan) | 0.5 to 1.0 (5 to 10 lb) (1.5 to 2 pt) | Apply preplant incorporated in fall after September 1. Rate dependent on soil type. Do not apply in spring. | F7 |
| **propachlor** (Ramrod) | 4 (4 qts) | Apply preemergence for control of annual grasses and some broadleaf weeds. | F8 |
| **Postemergence** | | | |
| **barban** (Carbyne 2EC) | .25 to .37 (1 to 1.5 pts) | Apply postemergence for wild oat control. Apply when the majority of wild oats are in the 2-leaf stage. | |
| **bromoxynil** | | | |
| (Brominal ME4) | .25 to .5 (.5 to 1 pt) | Apply to flax 2 to 8 inches tall. Controls most broadleaf weeds. Flax injury possible. See narrative. | F3 |
| (Buctril) | .25 (1 pt) | Apply to flax 2 to 4 inches tall. Controls most broadleaf weeds. Flax injury possible. See narrative. | |
| **dalapon** (Dowpon) | .75 (1 lb) | Controls all annual grasses except wild oats. Apply before grasses are 2 inches tall. | F4 |
| Labeled mixture | | | |
| MCPA (ester or amine) | .25 | Adds broadleaf weed control. Apply to flax 2 to 6 inches tall. | |
| **diclofop** (Hoelon) | .75 to 1.0 (2 to 2.67 pt) | Apply postemergence for annual grass control, including wild oats. Apply when grasses are in the 1 to 4 leaf stage. Do not add crop oil concentrate. | F5 |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .375 to .5 | Adds broadleaf weed control. Flax injury is possible at the high rate. | |
| **MCPA** (amines or esters) | .25 (several formulations) | Controls most broadleaf weeds. Weak on wild buckwheat and smartweeds. Apply when flax is 2 to 6 inches tall. | F9 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

**Table F2. Effectiveness of herbicides on major weeds in flax.**

| Herbicides | Type of application | Flax tolerance | Grasses: Green & yellow foxtail | Grasses: Wild oats | Broadleafs: Common lambsquarters | Broadleafs: Common ragweed | Broadleafs: Kochia | Broadleafs: Pigweed spp. | Broadleafs: Smartweed spp. | Broadleafs: Wild mustard |
|---|---|---|---|---|---|---|---|---|---|---|
| barban (Carbyne 2EC) . . . . . . . . | POST | F | N | G | N | N | N | N | N | N |
| bromoxynil (Brominal ME4, Buctril) | POST | F | N | N | G | G | G | G | G | F |
| dalapon (Dowpon) . . . . . . . . . . | POST | F | G | N | N | N | N | N | N | N |
| diclofop (Hoelon). . . . . . . . . . | POST | G | G | G | N | N | N | N | N | N |
| EPTC (Eptam/Genep) . . . . . . . . . | PPI | F | G | F | F/G | F | F | F | P | P |
| trifluralin (Treflan). . . . . . . . | PPI | F | G | P | F | N | F | G | F | N |
| propachlor (Ramrod). . . . . . . . . | PRE | G | G | P | F | F | G | G | P | P |
| MCPA amine . . . . . . . . . . . . . | POST | G | N | N | G | G | G | G | F | G |
| MCPA ester . . . . . . . . . . . . . | POST | F | N | N | G | G | G | G | F | G |

G = Good, F = Fair, P = Poor, N = None, PPI = Preplant incorporated, PRE = Preemergence, POST = Postemergence

## FORAGE LEGUME ESTABLISHMENT

### Cultural Practices

F1. Each year Minnesota farmers establish nearly one million acres of alfalfa and legume-grass mixtures for livestock feed. Most of this acreage is seeded with a companion crop such as oats, wheat, or flax. A companion crop is used to help crowd out weeds that otherwise would compete excessively with the forage legumes. However, this companion or "nurse" crop also competes with the forage legumes and often reduces the forage stand. Therefore, the companion crop should be harvested before the grain matures. Seeding alfalfa or other forage legumes alone in early spring with herbicides to control annual weeds is a relatively new method of legume establishment called "direct seeding." With this method there is little or no competition to the forage legumes, and better stands and higher yields are possible in the seeding year and subsequent years.

### Direct Seeding - Herbicides

F2. Seedling legumes generally are poor competitors with weeds. If the seeding is done in the spring, annual grasses such as the foxtails and annual broadleaf weeds such as pigweed and common lambsquarters usually compete aggressively with the legumes. Unless the field is relatively weed free or unless repeated tillage is used to kill seedling weeds prior to seeding, a herbicide usually is needed. If alfalfa or other forage legumes are direct-seeded with a herbicide, no forage grasses can be included in the mixture or they will be injured or killed. Direct seeding of alfalfa should not be attempted on steep slopes or other soils where wind or water erosion is a problem. On these sites, a companion crop will give more soil protection and can be used.

F3. Benefin (Balan) applied preplant incorporated will give good control of annual grasses and some broadleaf weeds. Wild oat and wild mustard control is not adequate. Apply preplant incorporated to alfalfa, red, alsike, and ladino clovers, and birdsfoot trefoil. Rate is dependent on soil type.

F4. EPTC (Eptam, Genep) should be applied preplant and incorporated immediately after application for annual grass and some broadleaf weed control in alfalfa, red and alsike clover, sweetclover, and birdsfoot trefoil. Wild oat and wild mustard control generally is not adequate. Rate is dependent on soil type.

F5. Trifluralin (Treflan) can be applied preplant incorporated for annual grass and some broadleaf weed control **only in legumes established on acres in a government set aside program. Do not use on acres not in a government program.** Some legume injury may occur. Rate dependent on soil type.

F6. Postemergence treatments of 2,4-DB amine or ester can be used to control annual broadleaf weeds. Use lower rates of ester formulations. The amine formulation can be used on alfalfa, red, alsike or ladino clover, and birsfoot trefoil. Ester formulations can be used on alfalfa and birdsfoot trefoil. Apply when legumes have 1 to 4 trifoliolate leaves and weeds are less than 3 inches tall.

**Companion Crop Seeding - Herbicides**

F7. Seedling stands of alfalfa, birdsfoot trefoil, and red, alsike or ladino clovers established with a small grain companion crop may be sprayed with some formulations of MCPA or 2,4-D amine (check the herbicide label). Do not use ester formulations. Serious legume injury can occur. Do not use these herbicides unless it is necessary to control severe infestations of broadleaf weeds. A canopy of grain or weeds will shield the legumes from the herbicide and help reduce legume injury. Reduced sprayer pressure and lower volume of spray may also help to minimize injury. Do not use these herbicides on sweet-clover.

## ESTABLISHED LEGUMES

### Cultural Practices

F8. Properly established stands of small-seeded legumes can effectively compete with many annual and perennial weeds. Weeds may become a problem if inadequate soil fertility, low soil pH, poor soil drainage, or poor management of the stand occurs. Maintaining proper soil fertility and pH levels will increase forage yields and increase legume growth and vigor for better competition with weeds. Many biennial and perennial weeds common in established legumes may be controlled effectively by harvesting the crop before weed seed formation and dispersal. If weed seeds do mature before the legume is ready for harvest, the forage should be ensiled, if possible. Fermentation in the silo kills many weed seeds.

F9. Weed control in forage crops does not often increase total dry matter production since the weeds are harvested along with the crop. However, since weeds are often less palatable and lower in protein than desirable forages, controlling weeds in forages can improve forage quality by increasing protein content, digestibility and consumption of forages.

### Herbicides

F10. Many of the biennial or perennial broadleaf weeds that are troublesome in alfalfa are deep rooted and similar to alfalfa in growth habit. These weeds are difficult to control with herbicides without injury to the alfalfa. On the other hand, quackgrass and other grass weeds that invade alfalfa are shallow rooted and are morphologically different enough from alfalfa so that control with herbicides is more feasible. However, the herbicides that control quackgrass also injure or kill most perennial forage grasses as well.

F11. Hexazinone (Velpar) is a newly registered herbicide for use in pure alfalfa stands, established for a year or more. It can be applied to dormant alfalfa in the fall or spring, or after a cutting and before alfalfa regrowth exceeds 1 to 2 inches. Treating regrowth greater than 2 inches tall will result in serious alfalfa injury. Lower rates of Velpar will control annual broadleaf weeds such as chickweed, buttercup, shepherdspurse, pennycress and yellow rocket. At least 1 lb/A (2 qts) is needed for dandelion, quackgrass and white cockle suppression. To avoid alfalfa injury do not overlap during application. Do not plant any crop within 12 months after an application of Velpar; after 12 months corn can be planted. Therefore, it is wise to wait to apply Velpar after a cutting in the spring to make sure the alfalfa stand was not winter killed. **Caution:** Do not graze or feed treated alfalfa for 30 days after application.

F12. MCPA can cause severe crop injury when used on established legumes and should be used only when a serious weed problem exists. MCPA should be applied only in late fall when legumes are dormant to control susceptible broad-leaved weeds that are present at this time. See the label for specific weeds. MCPA amine at 0.25 to 0.5 pound per acre may be used only on alfalfa and red clover to control certain winter annuals such as shepherdspurse and pennycress; some control of yellow rocket should result but white cockle is not controlled.

F13. Pronamide (Kerb) can be used on pure legume stands of alfalfa, clover, birdsfoot trefoil, or crown vetch to suppress quackgrass and other perennial grasses. Pronamide will also control many annual grasses and some annual broadleaf weeds but will not control perennial broadleaf weeds. Suggested rates are 1 to 2 pounds of pronamide per acre applied in the fall when soil temperatures are below 60°F but before freeze-up. The lower rate should be used on coarse textured soils and the higher rate on medium to fine textured soils. Applications may be made in the fall of the seeding year. **Caution:** Do not graze or harvest alfalfa within 25 to 45 days depending on rate of application. Do not graze or harvest clover, birdsfoot trefoil or crownvetch within 120 days of application.

F14. Simazine (Princep), wettable powder formulation (80W) and the water dispersible granular formulation (Caliber 90) may be applied to pure alfalfa stands established for a year or more to control seedling plants of wild mustard, yellow rocket, hoary alyssum, white cockle, shepherdspurse, and pennycress. Established plants, except hoary alyssum, are not consistently controlled. Application should be made after the last cutting in the fall and before the ground is frozen. Grasses in the alfalfa will be injured or killed. Some injury to alfalfa may occur. Recommended rates are 0.8 to 1.6 pounds per acre depending on soil type. Simazine should not be used on sands, loamy sands, gravelly soil, or on soils where soil pH is above 7.5. **Caution:** Do not graze areas treated with simazine for 30 days or cut hay for 60 days after treatment.

F15. Terbacil (Sinbar) may be applied to pure alfalfa stands established for one or more years at 0.5 to 1.5 pound per acre to control several annual grass and broadleaf weeds. Application may be made in the fall or spring while the alfalfa is dormant. There is potential for alfalfa injury, especially on sandy soils or soils with low organic matter. Other crops cannot be planted within 2 years after application.

F16. In established alfalfa, the amine salt of 2,4-DB can be applied at 0.5 to 1.5 pounds per acre or the ester of 2,4-DB can be applied at 0.5 to 1 pound per acre in 10 or more gallons of water per acre. Apply when the annual broadleaf weed seedlings are 1 to 3 inches tall (2- to 5-leaf stage). Do not apply when extremes of temperature or moisture are expected within the next few days. Late fall treatments are more effective on winter annuals than spring treatments. **Caution:** Do not graze for 60 days or feed hay for 30 days after application.

F17. Metribuzin (Lexone, Sencor) may be applied on alfalfa or alfalfa-grass mixtures at rates of 0.38 to 1 pound per acre to control certain grass and broadleaf weeds when the alfalfa is dormant in fall or spring. The higher rates will severely reduce forage grass stands. **Caution:** Do not graze or harvest within 28 days after application.

Table F1. Summary of herbicides for use in direct seeded forage legumes.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **benefin** (Balan) | 1.125 to 1.5 (6 to 8 pts) | Apply preplant incorporated for annual grass and some broadleaf weed control. Can be used on alfalfa, red, alsike and ladino clover, and birdsfoot trefoil. | F3 |
| **EPTC** (Eptam/Genep) | 2 to 4 (2.25 + 4.5 pts) | Apply preplant incorporated for annual grass and some broadleaf weed control. Can be used on alfalfa, red or alsike clover, sweetclover, and birdsfoot trefoil. | F4 |
| **trifluralin** (Treflan) | .50 to .75 (.1 to 1.5 pts) | **For annual grass and some broadleaf weed control only in forage legumes used as a cover crop in the acreage conservation reserve program or set-aside program.** Apply preplant incorporated. | F5 |
| **2,4-DB** (Butyrac, Butoxone)<br>(amine)<br>(ester) | .5 to 1.5<br>.5 to 1.5<br>.5 to 1 | Apply postemergence for annual broadleaf weed control when legumes have 2 to 4 trifoliolates and weeds are small. Amine formulation can be used on alfalfa, red, alsike or ladino clover, birdsfoot trefoil. Ester formulations can be used on alfalfa and birdsfoot trefoil. Use lower rates of ester formulations. | F6 |
| **MCPA** (amine) | .12 to .25 (several formulations) | Use amine formulation only. Legumes may be injured. Use only to control heavy stands of broadleaf weeds. Do not use on sweetclover. | F7 |
| **2,4-D** (amine) | .12 to .25 (several formulations) | Use amine formulation only. Legumes may be injured. Use only to control heavy stands of broadleaf weeds. Do not use on sweetclover. | F7 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

Table F2. Summary of herbicides for use in companion crop seeding of legumes.

| Herbicide | Active ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **MCPA** (amine) | .12 to .25 (several formulations) | Use amine formulation only. Legumes may be injured. Use only to control heavy stands of broadleaf weeds. Do not use on sweetclover. | F7 |
| **2,4-D** (amine) | .12 to .25 (several formulations) | Use amine formulation only. Legumes may be injured. Use only to control heavy stands of broadleaf weeds. Do not use on sweetclover. | F7 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

**Table F3. Effectiveness of herbicides on major weeds in legumes.**

| Herbicides | Type of application | Legume tolerance | Grasses: Giant foxtail | Grasses: Green and yellow foxtail | Grasses: Wild oats | Broadleafs: Common lambsquarters | Broadleafs: Common ragweed | Broadleafs: Kochia | Broadleafs: Pigweed spp. | Broadleafs: Smartweed spp. | Broadleafs: Wild mustard |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Seeded** | | | | | | | | | | | |
| benefin (Balan). . . . . . . . | PPI | G | G | G | P | F | N | G | G | P | N |
| EPTC (Eptam/Genep) . . . . . . | PPI | F | G | G | F | F | F | F | F | P | P |
| trifluralin (Treflan). . . . . | PPI | F | G | G | P | G | N | G | G | P | N |
| 2,4-DB (Butyrac, Butoxone) . . | POST | F | N | N | N | G | G | F | G | P | G |
| **Companion Crop Seeded** | | | | | | | | | | | |
| MCPA amine . . . . . . . . . . . | POST | P | N | N | N | G | G | F | G | P | G |
| 2,4-D amine. . . . . . . . . . . | POST | P | N | N | N | G | G | G | G | P | G |

G = Good; F = Fair; P = Poor; N = No control
PPI = Preplant incorporated, POST = Postemergence

Table F4. Summary of herbicides for use in established legumes.

| Herbicide | Active ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **hexazinone**<br>(Velpar) | .5 to 1.5<br>(1 to 3 qt.) | Apply only to alfalfa. Apply late fall or early spring when alfalfa is dormant, or after cutting and before regrowth. May injure alfalfa. | F11 |
| **MCPA**<br>(amine) | .25 to .50<br>(Several formulations) | Apply to alfalfa only in late fall to dormant alfalfa. May injure alfalfa. | F12 |
| **pronamide**<br>(Kerb) | 1.0 to 2<br>(2 to 4 lbs.) | Apply to alfalfa, clovers, birdsfoot trefoil or crownvetch in fall when soil temperatures are less than 60° F, but before freeze-up. May injure alfalfa. | F13 |
| **simazine**<br>(Princep) | .8 to 1.6<br>(Several formulations) | Apply to alfalfa only in fall after last cutting, but before soil freeze-up. May injure alfalfa. | F14 |
| **terbacil**<br>(Sinbar) | .5 to 1.5<br>(.63 to 1.88 lbs.) | Apply to alfalfa only in late fall or early spring when alfalfa dormant. May injure alfalfa. | F15 |
| **2,4-DB**<br>(amine)<br>(ester) | .5 to 1.5<br>.5 to 1.5<br>.5 to 1 | Apply to alfalfa when annual broadleaf weeds are 1 to 3 inches tall. May injure alfalfa. | F16 |
| **metribuzin**<br>(Sencor 4L,/Lexone 4L) | .38 to 1<br>(.75 to 2 pt) | Apply late fall or early spring to dormant alfalfa. May injure alfalfa. | F17 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

**Table F5. Effectiveness of herbicides on major weeds in legumes**

| Herbicides | Legume tolerance | Green & yellow foxtail | Quackgrass | Wirestem muhly | Bull thistle | Canada thistle | Common dandelion | Curly dock | Field pennycress | Hemp dogbane | Hempnettle | Hoary alyssum | Narrowleaf hawksbeard | Orange hawkweed | Oxeye daisy | Perennial sowthistle | Shepherdspurse | Spotted knopweed | Tansy | Virginia pepperweed | White cockle | Yellow rocket |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| glyphosate (Roundup) . . . . . . . | N | G | G | G | G | G | G | G | G | F | F | G | F | F | F | G | G | G | F | G | G | G |
| hexazinone (Velpar). . . . . . . . | F | G | S | S | N | N | S | F | G | N | N | F | P | N | N | N | G | N | N | G | S | G |
| MCPA . . . . . . . . . . . . . . . | F | N | N | N | F | P | P | P | G | P | N | P | P | P | P | P | G | P | N | G | P | F |
| pronamide (Kerb) . . . . . . . . . | G | G | S | S | P | N | N | N | P | N | N | N | N | N | N | N | P | P | N | P | N | N |
| simazine (Princep) . . . . . . . . | F | G | F | F | F | P | P | P | G | P | N | F | P | P | P | P | G | F | N | G | F | F |
| terbacil (Sinbar). . . . . . . . . | F | N | P | P | F | P | F | P | G | P | N | P | P | P | P | N | G | F | N | G | F | F |
| 2,4-DB . . . . . . . . . . . . . . | F | N | N | N | F | P | P | P | G | N | N | P | N | N | N | P | G | F | N | G | P | P |
| metribuzin (Sencor/Lexone) . . . . | F | F | P | P | F | P | F | F | G | P | N | P | P | P | P | N | G | F | N | G | F | F |

G = Good, F = Fair, P = Poor, N = No control, S=Suppression

## ESTABLISHED GRASS PASTURES

GP1. Broadleaf weeds, many of them on the noxious weed list and several of them poisonous to livestock, infest considerable grass pasture acreage in Minnesota. These broadleaf weeds are generally less palatable, less nutritious, lower yielding, and are less dependable as a forage supply for livestock than the desirable grass or legume pasture species that they replace.

### Cultural Practices

GP2. In established pastures, good management and controlled grazing are necessary to maintain a productive, weed-free stand. Protect new seedings from grazing until they are well established and graze moderately thereafter. Allowing established pastures a recovery period after grazing by excluding cattle for 3 to 4 weeks, on a rotational basis, will reduce weeds and increase forage yields. Mowing after each grazing period will control many pasture weeds and encourage new forage growth. Do not clip closer than 3 to 4 inches above the soil. In very weedy pastures where perennial grasses are thin, reseeding may be the best practice. To be successful, add lime and fertilizer according to soil test, destroy old sod and weeds by plowing or extensive surface tillage and seed an adapted mixture of legumes and grasses in a firm seedbed.

### Herbicides

GP3. Many years of research data and practical farmer use have shown that herbicides labeled for use in pastures are not harmful to livestock when applied on pasture grass and weeds at recommended usage rates following label restrictions. Because applied herbicides may make toxic weeds more palatable to livestock. Livestock should be excluded from the sprayed area for 7 to 10 days after treatment if poisonous plants are present. Follow grazing restrictions and safety precautions as prescribed on the label for the specific herbicide used. All the herbicides labeled for use in grass pastures will severely injure or kill legumes. Therefore, if legumes are present, and desirable, only spot treatments should be used.

GP4. Annual and biennial weeds are easiest to control with herbicides early in the first year of growth, after they have germinated and leafed out but while they are still small. Biennial and winter annual weeds also may be effectively controlled with herbicides in the fall of the seedling year when they are in the rosette stage. Perennial weeds that arise from a parent rootstock or underground rhizome, on the other hand, are best controlled with herbicides when they are at least 6 to 8 inches tall but before the bloom stage. During this growth stage, the perennial weeds are large enough to intercept an adequate amount of foliar herbicide to translocate enough into the root system to kill the weed. Also, during this growth stage, translocation (of sugars produced in the leaves) is from leaf shoot to root rather than from root to shoot; this favors movement of the herbicide into the perennial root system and makes root kill more likely.

GP5. Dicamba (Banvel) is cleared for broadleaf weed control in grass pastures. The suggested rate of application ranges from 0.25 pound per acre for susceptible annuals to 4 to 8 pounds per acre for the harder to control perennials. Mixtures of 0.5 to 1 pound per acre with 2,4-D will give better control of 2,4-D-resistant species. The higher rates of dicamba should only be used for spot treatment of perennial broadleaf weeds. Do not apply on or near desirable trees or plants or in locations where the chemical may be washed or moved into contact with the roots of desirable plants. Prevent drift of dicamba to desirable plants, particularly soybeans. **Caution:** After treatment of pastures with dicamba, do not graze dairy animals for 7 to 60 days nor harvest for hay for 37 to 90 days depending on the rate of application. See label for details. There is no waiting period between treatment and grazing for animals other than dairy animals; except, do not graze meat animals in treated fields within 30 days of slaughter.

GP6. Glyphosate (Roundup) can be applied as a spot treatment or applied with a wiper applicator for the control of many annual and perennial weeds. No more than one-tenth of any acre should be treated at one time. **Caution:** Remove all livestock before application and wait 14 days after application before grazing livestock or harvesting.

GP7. MCPA and 2,4-D can be applied for the control of many annual and perennial weeds. Repeated treatment for 2 or more years is usually necessary for adequate control of perennial weeds. Use lower rates of the ester formulations. **Caution:** Do not graze dairy cows for 7 to 14 days after a 2,4-D or MCPA treatment. Do not cut 2,4-D treated grass for hay within 30 days after application.

GP8. Picloram (Tordon) applied at 0.5 to 2 lbs/A (1 to 4 qts) will control many annual and perennial broadleaf weeds. Only use the high rate for spot treating. Picloram is usually tank mixed with 2,4-D. Do not apply directly to standing or running water. Do not apply where surface water from treated areas can run off to adjacent cropland. **Caution:** Do not graze dairy animals for 14 days after application. Meat animals grazing for up to 2 weeks after treatment should be removed from treated areas 3 days prior to slaughter.

Table GP1. Summary of herbicides for use in established grass pastures.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **dicamba** | 0.25 to 2 | Annual and perennial broadleaf control. Use low rate for broadcast application. Only use high rates for spot treatments. See narrative for grazing restrictions. | GP5 |
| (Banvel) | (.25 to 2 qts) | | |
| (Banvel II) | (.5 to 4 qts) | | |
| Labeled mixtures | | | |
| 2,4-D | 0.25 to 2 (several formulations) | Use lower rate of dicamba when tank mixed with 2,4-D. See narrative for grazing restrictions. | |
| **glyphosate** (Roundup) | | For spot treatment with a wiper applicator for control of many annuals and perennial weeds. | GP6 |
| **MCPA** (ester or amine) | 0.25 to 2 (several formulations) | Use high rates for perennial weeds. Use either ester or amine formulations. See narrative for grazing restrictions. | GP7 |
| **picloram** (Tordon) | 0.5 to 2 (1 to 4 qts) | Annual and perennial broadleaf weed control. Use low rate for broadcast applications. Only use high rates for spot treatments. See narrative for grazing restrictions. **Restricted use herbicide.** | GP8 |
| Labeled mixtures | | | |
| 2,4-D | 1 to 2 | Use lower rate of picloram in tank mixes with 2,4-D. | |
| **2,4-D** (ester or amine) | 0.5 to 2 (several formulations) | Use high rate for perennial or biennial weeds. Use either ester or amine formulations. See narrative for grazing restrictions. | GP7 |

*Reference number indicates appropriate paragraph in the narrative.

**Table GP2. Effectiveness of herbicides on major weeds in grass pastures.**

| Herbicides | Alyssum, hoary* | Aster spp. | Bracken fern* | Burdock | Buttercup spp.* | Daisy, spp. | Dandelion | Dock, curly | Goldenrod spp. | Hawksbeard spp. | Hawksweed* | Hemp* | Horseweed | Knapweed, spotted | Mullein | Nettle, stinging | Plantain spp. | Sorrel, red | Snakeroot, white* | Sowthistle, perennial | Spurge, leafy | Tansy* | Thistle, Canada | Thistle, bull | Thistle, musk | Thistle, plumeless | Toadflax, yellow | Waterhemlock spp.* | Wormwood, absinthe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dicamba (Banvel) | F | G | F | G | G | F | G | G | G | F | F | G | F | G | F | F | G | G | G | G | F | G | G | G | G | G | P | F | G |
| glyphosate (Roundup) | G | G | F | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | F | G | G | G | G | G | G | G | G |
| MCPA | F | F | P | G | G | F | G | F | F | P | P | G | F | G | P | F | G | N | F | F | N | N | F | G | F | F | N | F | P |
| picloram (Tordon) | G | G | F | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G | G |
| 2,4-D | F | F | P | G | F | F | G | F | F | P | F | G | F | G | P | G | G | N | F | F | P | F | F | G | G | G | N | G | F |

G = Good, F = Fair, P = Poor, N = No control
* May be poisonous to livestock.

## SMALL GRAINS

### Spring Wheat, Barley and Oats

SG1. Effective weed control in field crops can usually be accomplished with a combination of cultural, mechanical, and chemical practices. In row crops, tillage can be an integral part of weed control. However, in close-sown small grain crops, tillage is not feasible, except that early germinating weeds may be destroyed by tillage during seedbed preparation. Therefore, more dependence on cultural and chemical weed control practices is needed.

### Cultural Practices

SG2. Sowing clean seed at an adequate seeding rate will help to reduce weed populations in small grains. Also, small grains must be seeded early so the cool season small grain crop can compete effectively with weeds. Early spring seeding reduces warm season annual grass weed problems, such as foxtail, that are increased by late seeding. However, early spring seeding does not help to reduce wild oats or most annual or perennial broadleaf weed problems. These weeds must be controlled with herbicides because delayed seeding with repeated tillage to control these weeds results in reduced small grain yields.

### Perennial Weed Control

SG3. Most herbicides available for use in small grains will control many annual weeds at safe usage rates for small grain, but will not control established perennials. Perennial weeds such as Canada thistle or quackgrass should be controlled prior to (preferably the year before) seeding small grains. Glyphosate (Roundup) may be used to control most perennials prior to seeding small grain. See the glyphosate label and Table GS1 for more details. Also, many perennial broadleaf weeds can be controlled with 2,4-D or dicamba (Banvel) in the fall prior to seeding small grain. See perennial weed control section for additional information.

### Herbicides

SG4. The number of weed species controlled is often increased when post-emergence herbicides are applied to fields already treated with a preemergence or preplant herbicide. Also, combinations of certain postemergence or preemergence herbicides may give better weed control than an individual herbicide used alone. For example, a tank mix of bromoxynil (Brominal ME4, Buctril) and MCPA gives greater wild mustard control than with either of these herbicides alone. However, loss of weed control or increased crop injury may also result from the use of certain herbicide combinations. For example, the mixing of diclofop (Hoelon) and 2,4-D will decrease the grass control of diclofop. Herbicides combinations should be used with caution until experience or research has shown that the herbicide is effective and safe.

SG5. When planning your weed control program, consider herbicide effectiveness, crop tolerance and herbicide cost. Accurately identify the weed problem and then select the most effective herbicide. For example, wheat and oats are more tolerant to dicamba (Banvel) than barley. Herbicide cost should also be a consideration when planning a weed control program. Many herbicides will control the same weeds; however, one herbicide may be more economical than the other. Accurate calibration of your spray equipment will also help reduce weed control costs and increase the effectiveness of the herbicides used. Underapplication of herbicides often results in poor weed control, and overapplication increases your weed control costs and may result in grain injury.

SG6. Barban (Carbyne 2E) can be applied to all varieties of spring wheat, durum and barley. Do not apply to oats. Barban should be applied at 0.25 to .38 lb/A (1 to 1.5 pts) when the majority of wild oats are in the 2-leaf stage. If the first application is missed, a single application of 0.5 lb/A (2 pts) may be made when the majority of wild oats are in the 2.5 to 3.5 leaf stage. Do not apply the 0.5 lb/A (2 pt) rate to durum wheat. Thick stands of small grain help suppress wild oats and enhance the control obtained with barban. Do not mix barban with 2,4-D, MCPA, or dicamba because wild oats control will be reduced. Barban may be mixed with 1 gallon/A aqueous nitrogen for increased wild oats control, when plants are growing under low fertility or drought stress. Barban can be tank mixed with dicofop (Hoelon) or difenzoquat (Avenge) to improve wild oats control.

SG7. Bromoxynil (Brominal ME4 or Buctril) can be applied to all varieties of spring wheat, durum, barley and oats from the emergence of the crop until boot stage. Bromoxynil controls many annual broadleaf weeds, including wild buckwheat and smartweeds. However, bromoxynil is weak on wild mustard. Bromoxynil should be applied before the four leaf stage of the weeds. Bromoxynil should be applied through flat fan nozzles, in a minimum of 10 gallons per acre and no less than 30 pounds pressure. Good coverage is essential for good weed control. Mixtures of bromoxynil plus MCPA ester (Bronate, 3 + 3 Brominal) applied from the 3-leaf to early boot stage will improve wild mustard control.

SG8. Chlorsulfuron (Glean) controls most annual broadleaf weeds in wheat preemergence and wheat, barley and oat postemergence. Chlorsufuron also suppresses green and yellow foxtail when applied preemergence or early postemergence. Chlorsulfuron use is limited in Minnesota because of its soil pH restrictions. Do not apply to soils with pH greater than 7.5. Because of soil residual, chlorsulfuron should only be applied to fields that will be in small grains (wheat, barley or oats) for up to 3 years. Therefore, future cropping rotations should be taken into consideration before using chlorsulfuron.

SG9. Dicamba (Banvel) controls many broadleaf weeds, including wild buckwheat and smartweed in wheat, barley and oats. However, dicamba is weak on wild mustard. Dicamba can be applied alone, but is usually applied in tank mixes with 2,4-D, bromoxynil or MCPA. Oats are more tolerant to dicamba than wheat or barley. Barley has only marginal tolerance to dicamba, therefore dicamba should not be applied to barley unless some injury is acceptable. Apply to barley in the 2 to 3-leaf stage. Dicamba should be applied to wheat and oats when these crops are in the 2 to 4-leaf stage. Apply to barley in the 2 to 3-leaf stage.

SG10. Diclofop (Hoelon) applied at 0.75 to 1.25 lb/A (2 to 3.3 pt) in spring wheat and durum and 0.75 to 1.0 lb/A (2 to 2.67 pt) in barley will control wild oats and other annual grasses. Do not use in oats. Apply to weeds in the 1 to 4-leaf stage. Addition of a crop oil concentrate at 1 qt/A to the 0.75 lb/A (2 qt) of diclofop has been shown to increase wild oats control. Addition of crop oil concentration to higher rates of diclofop has not significantly increased control. Do not use crop oil concentrate on barley. Diclofop should not be tank mixed with any broadleaf herbicide other than bromoxynil and a low rate (0.05 lb/A) of MCPA ester or reduced grass weed control will result. A package mix of diclofop + bromoxynil + MCPA (One Shot) is available.

SG11. Difenzoquat (Avenge) will control wild oats in spring wheat, durum, and barley. Do not apply to oats. Apply difenzoquat when the majority of wild oats are in the 3 to 5-leaf stage. Use the high rate when wild oat populations are high. Barley has good tolerance to difenzoquat, however, some spring wheat and durum varieties can be injured. Do Not apply difenzoquat to the durum wheat varieties of **Vic, Edmore, Lakota, and Wascana.** Difenzoquat Can Be applied to the spring wheat varieties of **Apex, Buckshot, Butte, Centa, Columbus, Coteau, Courtney, Era, Erik, Fortuna, Glenman, Leader, Marberg, Marshall, McKay, Newana, Norak, Norana, Oslo, Pioneer 2369, Pondera, Pro-Brand 711, and Wheaton.** Do Not apply difenzoquat to any other spring wheat variety as injury will result. Difenzoquat may be tank mixed with bromoxynil, MCPA, MCPA + bromoxynil, 2,4-D orchlorsulfuron for broadleaf weed control.

SG12. MCPA (amine or ester) will control many broadleaf weeds in spring wheat, durum, barley and oats. MCPA is weak on wild buckwheat and smartweeds. Small grains generally have a better tolerance to MCPA than to 2,4-D. Apply from the 2-leaf to early boot stage of the crop.

SG13. Picloram (Tordon) at 0.015 to 0.023 lb/A tank mixed with 2,4-D or MCPA is labeled for broadleaf weed control in spring wheat, barley and oats. Do not use on durum wheat. Do not tank mix with 2,4-D in oats. Apply picloram to the 3 to 5-leaf stage of the crop. Picloram residues may carry over in the soil, therefore do not rotate to a broadleaf crop following a picloram application.

SG14. Propanil + MCPA (Stampede CM) is a pre-mix that will control foxtails and some broadleaf weeds in barley, spring wheat, and durum. Do not apply to oats. Apply at the 2 to 5-leaf stage of spring wheat and the 2 to 4-leaf stage of durum and barley, and before the foxtails are beyond the 3-leaf stage. Temporary yellowing of the crop may occur, but research has shown that this yellowing will not cause a yield loss.

SG15. Triallate (Far-Go) applied at 1 to 1.25 lb/A to spring wheat and durum and at 1.24 to 1.5 lb/A to barley in the fall or spring will control wild oats. Triallate may be applied preplant incorporated or preemergence incorporated in the spring. Triallate is volatile and must be incorporated after application, except when applying the granule formulation in the fall. Triallate at 1 lb/A may be applied in combination with trifluralin (Treflan) at 0.5 to 0.75 lb/A for wild oats and foxtail control in spring wheat, durum, and barley in the spring after seeding.

SG16. Trifluralin (Treflan) at 0.5 to 0.75 lb/A may be applied in the fall preplant incorporated or preemergence incorporated in the spring for foxtail control in spring wheat, durum and barley. Do not use on oats. Trifluralin in the spring should be applied preemergence and shallowly incorporated twice at right angles with a harrow. The small grain should be seeded 2 to 2.5 inches deep to permit incorporation above the seed. Trifluralin may be applied in the spring preemergence incorporated in combination with triallate for wild oats and foxtail control.

SG17. 2,4-D (amine and ester) will control many broadleaf weeds in spring wheat, durum, barley and oats. Oat tolerance to 2,4-D is marginal and should only be applied if some crop injury is acceptable. 2,4-D is weak on wild buckwheat and smartweeds. Apply 2,4-D after the small grain has tillered and before the boot stage. Small grains may be sprayed with 2,4-D at 0.5 to 1 lb/A when the grains are in the dough stage to control large weeds that may interfere with harvest.

**Winter Wheat and Rye**

**Cultural Practices**

SG18. Winter annuals and/or perennials are usually the major weed problems in fall sown cereal grains. Perennial weeds should be controlled by tillage or herbicides before or during seedbed preparation. Seeding of winter wheat should be completed by September 20 and rye should be seeded by October 1 so the crops are well established before winter and able to compete well with weeds.

**Winter Wheat**

SG19. Many of the same herbicides used in spring sown small grains can also be used in winter wheat. However, the timing of these herbicides may be different.

SG20. Chlorsulfuron (Glean) may be applied preemergence in the fall or postemergence in the spring from the 2- to 3-leaf until the jointing stage of winter wheat. Do not use on soils over pH 7.5. Because of soil residue, chlorsulfuron should only be applied to fields that will be in small grains (wheat, barley, or oats) for up to 3 years.

SG21. Bromoxynil (Brominal ME4, Buctril) can be applied from wheat emergence until boot stage. Can be applied in the fall.

SG22. Dicamba (Banvel) can be applied prior to the jointing stage of wheat. Apply in the spring for less injury. Tank mix with MCPA or 2,4-D to increase wild mustard control.

SG23. MCPA and 2,4-D should be applied in the spring for broadleaf weed control. Apply MCPA from the 4-leaf stage until prior to boot stage. Apply 2,4-D after the wheat has tillered, but prior to boot stage.

**Rye**

SG24. Bromoxynil (Brominl ME4, Buctil), MCPA and 2,4-D are the only herbicides labeled for weed control in rye. Apply all three herbicides in the spring. Apply bromoxynil (Brominal ME4, Buctril) from emergence until early boot stage. Apply MCPA and 2,4-D in the spring until prior to boot stage. MCPA and 2,4-D are weak on wild buckwheat and smartweed. Since there are no herbicides available for grass weed control in rye, rye should not be seeded on fields that have a severe infestation of annual grass weeds.

Table SG1. Summary of herbicides for use in spring wheat, including durum.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **No-Till or Minimum Till** | | | |
| **chlorsulfuron** (Glean) | .016 to .05 (.33 to .5 oz) | Apply fall or spring prior to seeding wheat. Use .33 oz in fall. **Do not use on soil over pH 7.5.** See narrative for rotational restrictions and weeds controlled. | SG8 |
| **glyphosate** (Roundup) | .19 to .75 (.5 to 2 pts) | Apply prior to wheat emergence. Controls emerged annual grass and broadleaf weeds with no soil residual. Apply with nonionic surfactant. | |
| Labeled) mixtures | | | |
| dicamba (Banvel) | .12 to .25 | Improves broadleaf weed control when low glyphosate rate used. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control when low glyphosate rate used. | |
| **paraquat** (Gramoxone Super) | .25 to .5 (1.3 to 2.6 pts) | Apply prior to grain emergence but after weeds have emerged. No soil residual. Apply with Ortho X-77. **Restricted use herbicide.** | |
| **Preplant Incorporated or Preemergence** | | | |
| **chlorsulfuron** (Glean) | .008 to .016 (.16 to .33 oz) | Apply in fall or spring. Use .33 oz in fall. **Do not use on soil over pH 7.5.** See narrative for rotational restrictions and weeds controlled. | SG8 |
| **triallate** (Far-Go EC) (Far-Go Gran) | 1.0 (1.25 qt) (12.5 to 15 lb) | Apply fall or spring for wild oats control. Must be incorporated, except when applying Far-Go granules at 15 lb/A in fall. | SG15 |
| **trifluralin** (Treflan) (Treflan TR-10) | .5 to .75 (1 to 1.5 pts) (5 to 7.5 lbs) | Apply fall, granules perferred, or postplant spring, liquid formulation preferred. Must be incorporated. Apply after Sept. 1 for fall applications. | SG15, SG16 |
| Labeled mixture | | | |
| triallate (Far-Go) | 1 (1 qt) | Apply in spring only. Adds wild oats control. | |
| **Postemergence** | | | |
| **barban** (Carbyne 2EC) | .25 to .38 (1 to 1.5 pts) | Postemergence control of wild oats. Apply 1 to 1.5 pt/A to 2-leaf wild oats and 2 pt/A to 2.5 to 3.5-leaf wild oats. Do not use 2 pt/A on durum wheat. Control decreases as wild oats stage increases. | SG6 |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 | Adds broadleaf weed control. | |
| chlorsulfuron (Glean) | .008 to .024 | Adds broadleaf weed control. **Do not use on soil over pH 7.5.** Rotational crop restrictions. | SG8 |
| diclofop (Hoelon) | .25 to .5 | Apply to 1.5 to 4-leaf wild oats. Improves wild oats control and adds annual grass control. | |
| difenzoquat (Avenge) | .25 to .5 | Improves wild oats control. Apply to 1.5 to 5-leaf wild oats. See narrative for variety restrictions. | SG11 |

Table SG1. Continued.

| Herbicide | Active ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **bromoxynil** | .25 to .5 | Apply from crop emergence until boot stage. Postemergence control of most small broadleaf annual weeds. Weak on wild mustard. | SG7 |
| (Brominal ME4) | (.5 to 1 pt) | | |
| (Buctril) | (1 to 2 pts) | | |
| Labeled mixtures - **Brominal ME4** | | | |
| barban (Carbyne 2EC) | .38 | Adds wild oats control. Apply when wild oats are in the 2-leaf stage. | |
| dicamba (Banvel) | .03 to .06 | Apply to 2 to 4-leaf wheat. Improves broadleaf weed control. | |
| diclofop (Hoelon) | 1 to 1.25 | Adds wild oats and other annual grassy weed control. Apply when wild oats are in the 2 to 4-leaf stage. **Restricted use herbicide.** | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. Apply when wild oats are in the 3 to 5-leaf stage. See narrative for wheat variety restrictions. | SG11 |
| MCPA | .09 to .5 | Improves broadleaf weed control. Apply from 2-leaf to early boot stage of wheat. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control. Apply to wheat in the 5-leaf stage until just prior to boot stage. | |
| Labeled mixtures - **Buctril** | | Apply when wheat is in the 2 to 3-leaf stage until prior to boot stage. | |
| chlorsulfuron (Glean) | .008 to .024 | Adds residual broadleaf weed control and foxtail suppression. **Do not use on soils over pH 7.5.** Rotational crop restrictions. | SG8 |
| diclofop (Hoelon) | .75 to 1.25 | Adds wild oats and other annual grassy weed control. Apply when grassy weeds are in the 2 to 4-leaf stage. **Restricted use herbicide.** | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. Apply to 3 to 5-leaf wild oats. See narrative for wheat variety restrictions. | SG11 |
| MCPA | .25 to .5 | Improves broadleaf weed control. Apply to wheat after tillering but before boot stage. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control. Apply to wheat after tillering but before boot stage. | |
| **chlorsulfuron** | .008 to .016 | Controls most broadleaf weeds and suppresses foxtails. Apply from the 2 to 3-leaf until jointing stage of wheat, except for the durum variety, Vic. Apply to Vic after tillering but before jointing. See narrative for cropping restrictions. **Do not use on soils over pH 7.5.** | SG8 |
| (Glean) | (.16 to .33 oz) | | |
| Labeled mixtures | | | |
| barban (Carbyne 2EC) | .25 to .75 | Adds wild oats control. Apply to 2-leaf wild oats. | |
| bromoxynil (Buctril) | .25 to .38 | Improves broadleaf weed control. | |
| dicamba (Banvel, Banvel II) | .06 to .12 | Improves broadleaf weed control. | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. See narrative for variety restrictions. | SG11 |
| **dicamba** | .06 to .125 | Apply before wheat is in the 5-leaf stage. Applying at the 2 to 4-leaf stage will increase safety. Controls many broadleaf weeds including wild buckwheat and smartweeds. Weak on wild mustard. Most commonly used in in tank mixes. | SG9 |
| (Banvel) | (.12 to .25 pt) | | |
| (Banvel II) | (.25 to .5 pt) | | |

Table SG1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtures | | | |
| chlorsulfuron (Glean) | .008 to 0.016 | Adds residual broadleaf weed control and foxtail suppression. **Do not apply on soils over pH 7.5.** See narrative for cropping restrictions. | SG8 |
| bromoxynil (Buctril) | .25 to .38 | Improves broadleaf weed control. | |
| MCPA | .25 to .38 | Improves broadleaf weed control, especially wild mustard. Apply when wheat is in the 4-leaf stage. Proper timing of application is important to avoid crop injury. | |
| **diclofop** (Hoelon) | .75 to 1.25 (2 to 3.3 pts) | Apply when wild oats and other annual grasses are in the 1 to 4-leaf stage. Apply before wheat is in the jointing stage. **Restricted use herbicide.** | SG10 |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .37 to .5 | Adds broadleaf weed control. | |
| MCPA ester | 0.05 | Can be added to a tank mix of diclofop plus bromoxynil to improve wild mustard control. Available as a package mix sold under the trade name One Shot. | |
| **difenzoquat** (Avenge) | .62 to 1 (2.5 to 4 pts) | For wild oats control in some varieties of spring wheat and durum. See narrative. Apply to 3 to 5-leaf stage wild oats. | SG11 |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .38 to .5 | Adds broadleaf weed control. | |
| chlorsulfuron (Glean) | .008 to .016 | Adds broadleaf weed control and foxtail suppresssion. See narrative for restrictions. | SG8 |
| MCPA | .25 to 1 | Adds broadleaf weed control. Apply to wheat in the 2-leaf to early boot stage. | |
| 2,4-D | .25 to .75 | Adds broadleaf weed control. Apply to wheat in the 5-leaf stage until just prior to boot stage. | |
| **MCPA** (Amines) | .25 to .66 (several formulations) | Controls many broadleaf weeds, but weak on wild buckwheat and smartweeds. Apply from 2-leaf to early boot stage of wheat. | |
| (Esters) | .16 to .5 (several formulations) | | |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 to .38 | Improves wild buckwheat and smartweed control. | |
| dicamba (Banvel) | .06 to .12 | Improves wild buckwheat and smartweed control. Apply when wheat is in the 2 to 4-leaf stage. | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. See narrative for variety restrictions. | SG11 |
| picloram (Tordon) | .015 to .023 | Improves wild buckwheat and smartweed control. See narrative for cropping restrictions. **Restricted use herbicide.** | SG13 |

Table SG1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **propanil + MCPA ester pre-mix** (Stampede CM) | .94 to .25 (2.5 pts) | For control of foxtails and some broadleaf weeds. Apply at 2 to 5-leaf stage of spring wheat, 2 to 4-leaf stage of durum, and 1 to 3 leaf stage of foxtails. Temporary yellowing of wheat may occur. | SG14 |
| **2,4-D** | | | |
| (Amines) | (.25 to .66) (several formulations) | Controls many broadleaf weeds. Weak on wild buckwheat and smartweeds. Apply when wheat is at the 5-leaf stage until just prior to boot. | SG17 |
| (Esters) | (.16 to .5) (several formulations) | | |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 to .38 | Improves wild buckwheat and smartweed control. | |
| dicamba (Banvel) | .06 | Improves wild buckwheat and smartweed control. Apply when wheat is in the 4-leaf stage. Proper timing of application is important to avoid crop injury. | |
| picloram (Tordon) | .015 to .023 | Improves wild buckwheat control. Do not use on durum wheat. See narrative for cropping restrictions. **Restricted use herbicide.** | SG13 |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. See narrative for variety restrictions. | SG11 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

Table SG2. Summary of herbicides for use in barley.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **No-Till or Minimum Till** | | | |
| **glyphosate** | .19 to .75 | Apply prior to barley emergence. Controls emerged annual grassy and broadleaf | |
| (Roundup) | (.5 to 2 pts) | weeds with no soil residual. Apply with nonionic surfactant. | |
| Labeled mixtures | | | |
| dicamba (Banvel) | .12 to .25 | Improves broadleaf weed control when low glyphosate rate used. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control when low glyphosate rate used. | |
| **paraquat** | .25 to .5 | Apply prior to grain emergence for control of emerged weeds. No soil residual. | |
| (Gramoxone Super) | (1.3 to 2.6 pts) | Apply with Ortho X-77. **Restricted Use Herbicide.** | |
| **Preplant Incorporated or Preemergence** | | | |
| **triallate** | 1.25 | Apply fall or spring for wild oats control. Must be incorporated after | SG15 |
| (Far-Go EC) | (1.25) | application, except when applying Far-Go granules at 15 lb/A in fall. | |
| (Far-Go Gran) | (12.5 to 15 lb) | | |
| **trifluralin** | .5 to .75 | Apply fall, granules preferred, or postplant spring, liquid formulation | SG16 |
| (Treflan) | (1 to 1.5 pts) | preferred. Must be incorporated. Apply after Sept. 1 for fall applications. | |
| (Treflan TR-10) | (5 to 7.5 lbs) | | |
| Labeled mixture | | | |
| triallate (Far-Go) | 1 (1 qt) | Apply in spring only. Adds wild oats control. | SG15 |
| **Postemergence** | | | |
| **barban** | .25 to .38 | Postemergence control of wild oats. Apply 1 to 1.5 pt/A to 2-leaf wild oats | SG6 |
| (Carbyne 2EC) | (1 to 1.5 pts) | and 2 pt/A to 2.5 to 3.5-leaf wild oats. Control decreases as wild oats stage increases. | |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 | Adds broadleaf weed control. | |
| chlorsulfuron (Glean) | .008 to .024 | Adds broadleaf weed control. **Do not use on soil over pH 7.5.** | SG8 |
| diclofop (Hoelon) | .25 to .5 | Rotational crop restrictions. Apply to 1.5 to 4-leaf wild oats. Improves wild oats control and adds annual grass weed control. | |
| difenzoquat (Avenge) | .25 to .5 | Improves wild oats control. Apply to 1.5 to 5-leaf wild oats. | SG11 |
| **bromoxynil** | .25 to .5 | Apply from crop emergence until boot stage. Postemergence control of most | SG7 |
| (Brominal ME4) | (.5 to 1 pt) | small broadleaf annual weeds. Weak on wild mustard. | |
| (Buctril) | (1 to 2 pts) | | |
| Labeled mixtures - **Brominal ME4** | | | |
| barban (Carbyne 2EC) | .38 | Adds wild oats control. Apply when wild oats are at the 2-leaf stage. | |
| diclofop (Hoelon) | 1 to 1.25 | Adds wild oats and other annual grass weed control. Apply when wild oats are in the 1 to 4-leaf stage. **Restricted use herbicide.** | |

Table SG2. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| difenzoquat (Avenge) | .62 to 1 | Adds wild oat control. Apply when wild oats are in the 3 to 5-leaf stage. | SG11 |
| MCPA | .09 to .5 | Improves broadleaf weed control. Apply from 2-leaf to early boot stage of crop. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control. Apply to barley in the 5-leaf stage until just prior to boot stage. | |
| Labeled mixtures - **Buctril** | | Apply when barley is in the 2 to 3-leaf stage until prior to boot stage. | |
| chlorsulfuron (Glean) | .008 to .024 | Adds residual broadleaf weed control and foxtail suppression. **Do not use on soils over pH 7.5.** Rotational crop restrictions. | SG18 |
| diclofop (Hoelon) | .75 to 1.25 | Adds wild oats and other annual grass weed control. Apply when grassy weeds are in the 2 to 4-leaf stage. **Restricted use herbicide.** | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. Apply to 3 to 5-leaf wild oats. | SG11 |
| MCPA | .25 to .5 | Improves broadleaf weed control. Apply to barley after jointing but prior to boot stage. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control. Apply to barley after jointing but prior to boot stage. | |
| **chlorsulfuron** (Glean) | .008 to .016 (.16 to .33 oz) | Controls most broadleaf weeds and suppresses foxtails. Apply to barley from the 2 to 3 leaf stage until prior to boot stage. See narrative for cropping restrictions. **Do not use on soils over pH 7.5.** | SG8 |
| Labeled mixtures | | | |
| barban (Carbyne) | .25 to .75 | Adds wild oats control. Apply to wild oats in the 2-leaf stage. | |
| bromoxynil (Buctril) | .25 to .38 | Improves broadleaf weed control. | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. | SG11 |
| **dicamba** (Banvel) (Banvel II) | 0.09 (.19 pt) (.09 pt) | Apply before barley is in the 3-leaf stage. Potential for barley injury exists. Controls many broadleaf weeds including wild buckwheat and smartweeds. Weak on wild mustard. Most commonly used in tank mixes. Use lower rate in tank mixes. | SG9 |
| Labeled mixtures | | | |
| chlorsulfuron (Glean) | .008 to 0.02 | Adds residual broadleaf weed control and foxtail suppression. **Do not apply on soils over pH 7.5.** See narrative for cropping restrictions. | SG8 |
| MCPA | .25 to .38 | Improves broadleaf weed control, especially wild mustard. Apply before barley is in the 3-leaf stage. | |
| **diclofop** (Hoelon) | .75 to 1 (2 to 2.66 pt) | Apply when wild oats and other annual grasses are in the 1 to 4-leaf stage. Apply before barley is in the jointing stage. **Restricted use herbicide.** | SG10 |

Table SG2. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .37 to .5 | Adds broadleaf weed control. | |
| MCPA ester | 0.05 | Can be added to a tank mix of diclofop plus bromoxynil to improve wild mustard control. Available as a package mix sold under the trade name One Shot. | |
| **difenzoquat** (Avenge) | .62 to 1 (2.5 to 4 pts) | Wild oats control. Apply to 3 to 5-leaf stage wild oats. | SG11 |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .38 to .5 | Adds broadleaf weed control. | |
| chlorsulfuron (Glean) | .008 to .016 | Adds broadleaf weed control and foxtail suppresssion. See narrative for restrictions. | SG8 |
| MCPA | .25 to 1 | Adds broadleaf weed control. Apply to barley in the 2-leaf to early boot stage. | |
| 2,4-D | .25 to .75 | Adds broadleaf weed control. Apply to barley in the 5-leaf stage until just prior to boot stage. | |
| **MCPA** | | | |
| (Amines) | .25 to .66 (several formulations) | Controls many broadleaf weeds, but weak on wild buckwheat and smartweed. Apply from 2-leaf to early boot stage of barley. | SG12 |
| (Esters) | .16 to .5 (several formulations) | | |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 to .38 | Improves wild buckwheat and smartweed control. | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. | SG11 |
| picloram (Tordon) | .015 to .023 | Improves wild buckwheat control. Apply to barley in the 3 to 5-leaf stage. See narrative for cropping restrictions. **Restricted use herbicide.** | SG13 |
| **propanil + MCPA ester pre-mix** (Stampede CM) | .94 + .25 (2.5 pts) | For control of foxtails and some broadleaf weeds. Apply at 2 to 4-leaf stage of barley and 1 to 3 leaf stage of foxtails. Temporary yellowing of barley may occur. | SG14 |
| **2,4-D** | | | |
| (Amines) | (.25 to .66) (several formulations) | Controls many broadleaf weeds. Weak on wild buckwheat and smartweed. Apply when barley is at the 5-leaf stage until just prior to boot. | SG17 |
| (Esters) | (.16 to .5) (several formulations) | | |

Table SG2. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 to .38 | Improves wild buckwheat and smartweed control. | |
| picloram (Tordon) | .015 to .023 | Improves wild buckwheat control. See narrative for cropping restrictions. **Restricted use herbicide.** | SG13 |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. | SG11 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

**Table SG3. Summary of herbicides for use in oats.**

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **No-Till or Minimum Till** | | | |
| **glyphosate** (Roundup) | .19 to .75 (.5 to 2 pt) | Apply prior to oat emergence. Controls emerged annual grass and broadleaf weeds with no soil residual. Apply with nonionic surfactant. | |
| Labeled mixtures | | | |
| dicamba (Banvel) | .12 to .25 | Improves broadleaf weed control when low glyphosate rate used. | |
| 2,4-D amine | .25 to .5 | Improves broadleaf weed control when low glyphosate rate used. | |
| **Postemergence** | | | |
| **bromoxynil** (Brominal ME4) (Buctril) | .25 to .50 (.5 to 1 pt) (1 to 2 pts) | Controls most annual broadleaf weeds. Weak on wild mustard. Apply from oat emergence until boot stage. | SG7 |
| Labelled mixtures | | | |
| MCPA | .25 to .5 | Improves broadleaf weed control. Apply to oats in the 3-leaf stage until boot. | |
| 2,4-D | .25 to .50 | Improves broadleaf weed control. Apply to oats from tillering to early boot. **Oat injury is possible.** | |
| **chlorsulfuron** (Glean) | .008 to .016 (.16 to .33 oz) | Controls most broadleaf weeds and suppresses foxtails. Apply to oats from the 2 to 3-leaf stage until prior to boot. **Do not apply to soils over pH 7.5.** See narrative for rotational restrictions. | SG8 |
| **dicamba** (Banvel) (Banvel II) | .06 to .125 (.12 to .25 pt) (.25 to .5 pt) | Apply before 5-leaf stage of oats. Controls many broadleaf weeds, including wild buckwheat and smartweed. | SG9 |
| Labeled mixture | | | |
| MCPA | .25 to .375 | Improves wild mustard control. Apply before 5-leaf stage of oats. | |
| **MCPA** | .25 to .375 | Controls most broadleaf weeds. Weak on wild buckwheat and smartweeds. Apply to oats from emergence to boot stage. **Oat injury is possible.** | SG12 |
| Labeled mixtures | | | |
| dicamba (Banvel) | .06 to .125 | Apply before the 5-leaf stage of oats. Adds wild buckwheat and smartweed control. | |
| picloram (Tordon) | .015 to .023 | Apply to 3 to 5-leaf oats. Adds wild buckwheat control. See narrative for recropping restrictions. **Restricted use herbicide.** | SG13 |

*Reference paragraph number indicates appropriate paragraph in narrative.

**Table SG4. Summary of herbicides for use in winter wheat.**

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **No-Till or Minimum Till** | | | |
| **chlorsulfuron**<br>(Glean) | .008 to .016<br>(.16 to .33 oz) | Apply in fall prior to wheat emergence. **Do not use on soil over pH 7.5.** See narrative for rotational restrictions and weeds controlled. | SG20 |
| **glyphosate**<br>(Roundup) | .19 to .75<br>(.5 to 2 pts) | Apply prior to wheat emergence. Controls emerged annual grass and broadleaf weeds with no soil residual. Apply with nonionic surfactant. | |
| Labeled) mixtures | | | |
| dicamba (Banvel) | .12 to .25 | Improves broadleaf weed control when low glyphosate rate used. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control when low glyphosate rate used. | |
| **Preplant Incorporated or Preemergence** | | | |
| **chlorsulfuron**<br>(Glean) | .008 to .016<br>(.16 to .33 oz) | Apply in fall prior to wheat emergence. **Do not use on soil over pH 7.5.** See narrative for rotational restrictions and weeds controlled. | SG20 |
| **triallate**<br>(Far-Go EC)<br>(Far-Go Gran) | 1.0<br>(1.25 qt)<br>(12.5 to 15 lb) | Apply before or after planting for wild oat control. Must be incorporated. See narrative. | SG15 |
| **Postemergence** | | | |
| **barban**<br>(Carbyne 2EC) | .25 to .38<br>(1 to 1.5 pts) | Wild oats control. Apply when wild oats are in the 2-leaf stage. See narrative. | SG6 |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 | Adds broadleaf weed control. | |
| chlorsulfuron (Glean) | .008 to .024 | Adds broadleaf weed control. **Do not use on soil over pH 7.5.** See narrative for rotational restrictions. | SG20 |
| diclofop (Hoelon) | .25 to .5 | Apply to 1.5 to 4-leaf wild oats. Improves wild oats control and adds annual grass weed control. | |
| difenzoquat (Avenge) | .25 to .5 | Improves wild oats control. Apply to 1.5 to 5-leaf wild oats. **Do not apply to the variety Borah.** | SG11 |
| **bromoxynil**<br>(Brominal ME4)<br>(Buctril) | .25 to .5<br>(.5 to 1 pt)<br>(1 to 2 pts) | Apply from wheat emergence until boot stage. Can be applied in the fall. Postemergence control of most small broadleaf weeds. Weak on wild mustard. | SG21 |
| Labeled mixtures - **Brominal ME4** | | | |
| barban (Carbyne 2EC) | .38 | Adds wild oats control. Apply when wild oats are in the 2-leaf stage. | |
| dicamba (Banvel) | .03 to .06 | Apply to 3-leaf to joint stage wheat. Can be applied in fall. Improves broadleaf weed control. | |
| diclofop (Hoelon) | 1 to 1.25 | Adds wild oats and other annual grassy weed control. Apply when wild oats are in the 1 to 4-leaf stage. **Restricted use herbicide.** | |

Table SG4. Continued.

| Herbicide | Active ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. Apply to 3 to 5-leaf wild oats. **Do not apply to the variety Borah.** | SG11 |
| MCPA | .09 to .5 | Improves broadleaf weed control. Do not apply in the fall. Apply to 2-leaf to early boot stage wheat. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control. Do not apply in the fall. Apply to 5-leaf to early boot stage wheat. | |
| Labeled mixtures - **Buctril** | | | |
| chlorsulfuron (Glean) | .008 to .024 | Apply when wheat is in the 2 to 3-leaf stage until prior to boot stage. Adds residual broadleaf weed control and foxtail suppression. **Do not use on soil over pH 7.5.** See narrative for rotational cropping restrictions. | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. Apply to 3 to 5-leaf wild oats. **Do not apply to the variety Borah.** | |
| MCPA | .25 to .5 | Improves broadleaf weed control. Do not apply in the fall. Apply to 2-leaf to early boot stage wheat. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control. Do not apply in the fall. Apply to 5-leaf to early boot stage wheat. | |
| **chlorsulfuron** (Glean) | .008 to .016 (.16 to .33 oz) | Controls most broadleaf weeds and suppresses foxtails. Apply to wheat from the 2 to 3-leaf stage until jointing. **Do not use on soils over pH 7.5.** See narrative for cropping restrictions. | SG20 |
| Labeled mixtures | | | |
| barban (Carbyne 2EC) | .25 to .75 | Adds wild oats control. Apply to 2-leaf wild oats. | |
| bromoxynil (Buctril) | .25 to .38 | Improves broadleaf weed control. Can be applied in fall. | |
| dicamba (Banvel, Banvel II) | .06 to .12 | Improves broadleaf weed control. | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. **Do not apply to the variety Borah.** | |
| **dicamba** (Banvel) (Banvel II) | .06 to .125 (.12 to .25 pt) (.25 to .5 pt) | Apply prior to jointing stage. Apply in spring for less injury. Controls many broadleaf weeds including wild buckwheat and smartweeds. Weak on wild mustard. | SG22 |
| Labeled mixtures | | | |
| chlorsulfuron (Glean) | .008 to 0.016 | Improves broadleaf weed control and adds foxtail suppression. **Do not apply on soils over pH 7.5.** See narrative for cropping restrictions. | SG20 |
| bromoxynil (Buctril) | .25 to .38 | Apply prior to jointing stage. | |
| MCPA | .25 to .38 | Improves broadleaf weed control, especially wild mustard. Do not apply in fall. Apply prior to jointing stage. | |
| 2,4-D | .25 to .38 | Improves broadleaf weed control, especially wild mustard. Do not apply in fall. Apply prior to jointing stage. | |

Table SG4. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **diclofop** (Hoelon) | .75 to 1.25 (2 to 3.3 pts) | Apply when wild oats and other annual grasses are in the 1 to 4-leaf stage. Apply prior to jointing stage of wheat. **Restricted use herbicide.** | SG10 |
| Labeled mixtures | | | |
| chlorosulfuron (Glean) | .01 | Adds broadleaf weed control. **Do not use on soils over pH 7.5.** See narrative. | SG20 |
| bromoxynil (Buctril, Brominal ME4) | .37 to .5 | Adds broadleaf weed control. | |
| MCPA ester | 0.05 | Can be added to a tank mix of diclofop plus bromoxynil to improve wild mustard control. Do not exceed 1.5 fluid oz of MCPA. Available as a package mix - One Shot. | |
| **difenzoquat** (Avenge) | .62 to 1 (2.5 to 4 pts) | For wild oat control only. **Do not apply to the variety Borah.** Apply to 3 to 5-leaf wild oats. | SG10 |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .38 to .5 | Adds broadleaf weed control. | |
| chlorsulfuron (Glean) | .008 to .016 | Adds broadleaf weed control and foxtail suppresssion. See narrative for restrictions. | SG20 |
| MCPA | .25 to 1 | Adds broadleaf weed control. Apply before jointing stage of wheat. | |
| 2,4-D | .25 to .75 | Adds broadleaf weed control. Apply before jointing stage of wheat. | |
| **MCPA** | | | |
| (Amines) | .25 to .66 (several formulations) | Controls many broadleaf weeds, but weak on wild buckwheat and smartweeds. Apply before jointing stage of wheat. Spring application decreases injury. | SG23 |
| (Esters) | .16 to .5 (several formulation) | | |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 to .38 | Improves wild buckwheat and smartweed control. | |
| dicamba (Banvel) | .06 to .12 | Improves wild buckwheat and smartweed control. Apply before jointing stage of wheat. | |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. **Do not use on the variety Borah.** | SG11 |
| picloram (Tordon) | .015 to .023 | Improves wild buckwheat control. | SG13 |
| **2,4-D** | | | |
| (Amines) | (.25 to .66) (several formulations) | Controls many broadleaf weeds. Weak on wild buckwheat and smartweeds. Do not apply in fall. Apply after wheat has tillered, but before boot stage. | SG23 |
| (Esters) | (.16 to .5) (several formulations) | | |
| Labeled mixtures | | | |
| bromoxynil (Buctril, Brominal ME4) | .25 to .38 | Improves wild buckwheat and smartweed control. | |
| dicamba (Banvel) | .06 | Improves wild buckwheat and smartweed control. Do not apply in fall. Apply before jointing stage of wheat. | |
| picloram (Tordon) | .015 to .023 | Improves wild buckwheat control. See narrative for cropping restrictions. | SG13 |
| difenzoquat (Avenge) | .62 to 1 | Adds wild oats control. **Do not apply to the variety Borah.** | SG11 |

*Reference paragraph number indicates appropriate paragraph in narrative.

**Table SG5. Summary of herbicides for use in rye.**

| Herbicide | Active ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **bromoxynil** | .25 to .50 | Controls most annual broadleaf weeds. Weak on wild mustard. Apply in the spring prior to early boot stage. | SG23 |
| (Brominal ME4) | (.5 to 1 pt) | | |
| (Buctril) | (1 to 2 pts) | | |
| Labeled mixtures | | | |
| MCPA | .25 to .5 | Improves broadleaf weed control. Apply in the spring prior to boot stage. | |
| 2,4-D | .25 to .5 | Improves broadleaf weed control. Apply in the spring prior to boot stage. | |
| **MCPA** | .25 to .50 | Controls most broadleaf weeds. Weak on wild buckwheat and smartweeds. Apply in spring prior to boot stage. | SG23 |
| **2,4-D** | .25 to .50 | Controls most broadleaf weeds. Weak on wild buckwheat and smartweeds. Apply in spring prior to boot stage. | SG23 |

*Reference paragraph number indicates appropriate paragraph in narrative.

**Table SG6. Effectiveness of herbicides on major weeds in small grains.**[1,2]

| | | Grasses | | | | Broadleafs | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Herbicides** | **Type of application** | **Barnyardgrass** | **Green foxtail** | **Wild oats** | **Yellow foxtail** | **Canada thistle*** | **Cocklebur** | **Common ragweed** | **Eastern black nightshade** | **Field bindweed*** | **Giant ragweed** | **Kochia** | **Lambsquarters** | **Marshelder** | **Perennial sowthistle*** | **Pigweed** | **Russian thistle** | **Smartweeds (annuals)** | **Sunflower** | **Wild buckwheat** | **Wild mustard** |
| barban (Carbyne 2E). . . . . . . . . | POST | N | N | G | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| bromoxynil (Brominal ME4, Buctril) | POST | N | N | N | N | N | G | G | G | P | G | G | G | G | N | G | G | G | G | G | F |
| chlorsulfuron (Glean). . . . . . . | POST | G | G | P | G | G | G | G | N | F | G | G | G | - | F | G | G | G | G | G | G |
| dicamba (Banvel) . . . . . . . . . . | POST | N | N | N | N | G | G | G | G | G | G | G | G | G | G | G | F | G | G | G | P |
| diclofop (Hoelon). . . . . . . . . . | POST | G | G | G | F | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| difenzoquat (Avenge) . . . . . . . | POST | N | N | G | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| MCPA (amines or ester) . . . . . . | POST | N | N | N | N | F | G | G | G | G | G | G | G | G | F | G | N | P | F | P | G |
| picloram (Tordon). . . . . . . . . | POST | N | N | N | N | P | F | F | F | P | F | F | F | F | P | F | F | P | G | G | P |
| propanil + MCPA ester (Stampede CM) | POST | G | G | P | G | F | F | F | F | P | F | F | G | F | F | G | P | F | F | G | G |
| triallate (Far-Go) . . . . . . . . | PEI/ PPI | N | N | G | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| trifluralin (Treflan). . . . . . . | PEI/ PPI | G | G | P | G | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| 2,4-D (amine or ester) . . . . . . | POST | N | N | N | N | F | G | G | G | G | G | G | G | G | F | G | F | P | G | P | G |

* Only control of top, no control of roots.

[1] G = good; F = fair; P = poor; N = no control; - = inadequate information; POST = Postemergence; PEI = Preemergence incorporation; PPI = Preplant incorporated.

[2] Effectiveness ratings apply if herbicide is used according to label recommendations as to rate, time of application, etc., and if favorable temperature and moisture conditions prevail.

**Table SG7. Crop tolerance and herbicide clearance[1].**

| Herbicides | Barley | Oats | Rye | Wheat |
|---|---|---|---|---|
| barban | F | NC | NC | F |
| bromoxynil | G | G | G | G |
| chlorsulfuron | G | NC | NC | G** |
| dicamba | P | G | NC | F |
| diclofop | G | NC | NC | G |
| difenzoquat | G | NC | NC | * |
| MCPA amine | G | G | G | G |
| MCPA ester | G | G | G | G |
| picloram | G | G | NC | G |
| propanil + MCPA | G | NC | NC | G |
| triallate | G | NC | NC | G |
| trifluralin | F | NC | NC | F |
| 2,4-D amine | G | F | G | G |
| 2,4-D ester | G | P | F | F |

[1] P = poor; F = fair; G = good; NC = not cleared for use.
* Good tolerance on winter wheat and on spring wheat and durum wheat varieties listed on the label. Not cleared for use on other spring wheat varieties. See label.
**See label for use on Vic durum wheat.

## SOYBEANS

S1. Weeds can be most effectively managed in soybeans with a well-planned program that involves a thorough analysis of the field situation and use of a combination of cultural practices and appropriate herbicides. The most effective weed control system depends on the kinds of weeds in the field, soil characteristics, tillage practices, crop rotation, and soybean row width.

### Weed-Soybean Competition

S2. Weeds are vigorous competitors with soybeans. Weeds usually germinate and emerge with the soybeans, so the soybeans cannot get ahead of the weeds. Soybeans are relatively short and susceptible to shading from taller weeds. Weeds also compete with soybeans for nutrients and water. Since soybeans are especially sensitive to moisture deficiencies in late summer, a few large weeds can severely reduce yields. Nearly complete weed control must be accomplished within three to four weeks after emergence of the soybeans in order to avoid yield losses due to early emerging weeds. Planting narrow rows and following production practices which encourage vigorous soybean growth increases the crops competitive advantage over the weeds. The idea is to "shade out" late emerging weeds. In wider row spacings, a grower should strive to have the soybeans lapped in the row middles as soon as possible.

### Crop Rotation Practices

S3. Crop rotation can be an important component of a weed management program. Most annual broadleaf weeds can be more easily and/or more economically managed in corn than in soybeans. The opposite is true for most annual grass weeds. In addition, crop rotation encourages the use of different types (families) of herbicides on the same field over the years. This helps to prevent the accelerated microbial degradation of some herbicides, the soil residue buildup of some other herbicides, and the build-up of difficult to control weeds.

### Tillage Practices

S4. Several tillage practices aid weed management in soybeans. Seedbed preparation immediately prior to planting will kill weeds that have germinated. Killing these weeds is important in obtaining good results from preemergence herbicides. For effective weed control, herbicides applied premergence need to be moved into the soil by rainfall before weed seeds germinate. If rainfall has not been sufficient for herbicide activation, control the weed seedlings with a rotary hoe, harrow, or cultivator as soon as they emerge. Cultivation of weed escapes is an effective and economical weed control tool. Cultivation should be done when weeds are small and should be shallow (1 to 2 inches) to avoid soybean root damage.

### Herbicides

S5. Herbicides are the newest and often the most efficient weed management tool. Although herbicides have become a necessity in most soybeans production systems, far too many growers equate weed management solely with herbicides. Remember that herbicides are only one of the available weed control tools and that weed management is most successful and economical when all the tools for weed control are utilized in an integrated program.

S6. A herbicide or herbicide combination should be selected on the basis of its effectiveness on the different weed species in the field (Table S2). The correct herbicide rate must be used to obtain good weed control results and to minimize soybean injury (Table S1). Apply the proper herbicide at the prescribed time and rate with a carefully calibrated applicator to provide the best return on your investment. Always consult the herbicide labels for specific rates and instructions. Only chemicals that are cleared by the Environmental Protection Agency for the specific use intended should be used.

**No-Till or Minimum Till Herbicides**

S7. In no-till or minimum till soybean production, herbicides may be required to control or suppress emerged weeds. Glyphosate (Roundup) or paraquat (Gramoxone Super) are non-selective herbicides that will kill emerged weeds. These herbicides have no soil activity and are usually tank-mixed with other herbicides that provide residual control of later-germinating weeds (see table S1). **Paraquat is a restricted use herbicide.**

S8. Glyphosate (Roundup) is applied prior to soybean emergence for annual and perennial weed control in reduced tillage situations. Two rate structures exist for annual weed control. With low-volume applications (3 to 10 gallons/A), a rate of 0.5 to 2 pt/A plus 0.5 to 1% v/v of a nonionic surfactant can be applied to actively growing weeds 6 inches or less in height. Do not tank mix with soil residual herbicides at these rates. With high volume application (10 to 40 gallons/A), a rate of 2 to 3 pt/A should be used. Use the 2 pt/A rate on weeds less than 6 inches tall. Perennial weeds may not be at the proper stage of growth for control. However, 4 to 8 pt/A may suppress emerged perennials. See the perennial weed control section for additional information.

S9. Paraquat will no longer be distributed by Chevron Chemical Company. ICI Americas, Inc. will be the sole distributor of paraquat. As a result, ICI's Gramoxone Super will be the only formulation of paraquat on the market; Chevron's Paraquat Plus will no longer be available. Gramoxone Super will have a 1.5 lb/gal formulation, replacing the 2 lb/gal formulation of last year and the color will be blue-green instead of brown.

**Preplant Incorporated Herbicide Applications**

S10. Ethalfluralin (Sonalan), FMC-57020 (Command), pendimethalin (Prowl), trifluralin (Treflan), and vernolate (Vernam or Reward) all need to be incorporated for adequate weed control in soybeans. Trifluralin may also be applied and incorporated in the fall, after September 1. Vernolate should be incorporated immediately (within minutes) after application. Delays of incorporation of 3, 24, and 48 hours and 7 days after application are indicated on the labels for Command, trifluralin, ethalfluralin, and pendimethalin, respectively. Although delays in incorporation are allowed for some preplant incorporated herbicides, whenever possible immediate incorporation is recommended.

S11. Proper herbicide application and incorporation as well as favorable soil conditions are necessary for optimum herbicide performance. Ideally, the soil should be dry on the surface and moist, but not wet, just below the surface to ensure maximum mixing of herbicide and soil. To provide good control, adequate moisture is needed at the point where the emerging weed seedling contacts the herbicide. Good incorporation thoroughly mixes the herbicide with 2 to 3 inches of soil. For best results, incorporate the herbicide twice with a disk, field cultivator with sweep shovels, or similar implement, or once with a power-driven rotary tiller. The second incorporation should be carried out at a right angle to the direction of the first incorporation to ensure thorough mixing of the herbicide with the soil. Ethalfluralin (Sonalan), FMC-57020 (Command), and pendimethalin (Prowl) labels indicate that one herbicide incorporation may be adequate. The one pass incorporation may be effective, but is dependent upon the incorporation implement, soil type, moisture, and tilth and plant residue cover. Observe label instructions for specific incorporation procedures.

S12. Ethalfluralin (Sonalan), pendimethalin (Prowl), and trifluralin (Treflan) are all chemically related herbicides called dinitroanilines. Under cold or dry soil conditions these herbicides may persist for more than one year. Sensitive crops such as small grains, grain sorghum, or sugarbeets can be affected the following year. Some instances of corn injury from trifluralin carryover have been observed in Minnesota when recommended rates have been exceeded on lighter soil areas, in overlapping spray swaths, or in sprayer turn-around areas. Plowing with a moldboard plow, compared to reduced tillage systems, reduces the potential for crop injury from residues of these herbicides.

S13. FMC-57020 (Command) entered the soybean herbicide market in 1986 and was labeled for preplant incorporated and preemergence application. However, application of Command preemergence to moist or wet soil enhanced the volatilization of Command and allowed it to move off-target and injure sensitive species such as apple and peach trees, rose bushes, alfalfa, and oats. Command has a distinct whitening or yellowing effect on a sensitive plant's foliage. In order to reduce the potential for off-target movement Command must be applied to a dry soil and incorporated. The FMC label states that incorporation should be immediate whenever possible but must be done within 3 hours after application. The Elanco label calls for the immediate incorporation of tank mixtures containing ethalfluralin (Sonalan) or trifluralin (Treflan) and Command. As of the time of publication, Mobay's Sencor label is calling for incorporation within 3 hours after application of tank mixtures containing Command. Immediate incorporation is still highly recommended. Do not apply Command aerially or through irrigation equipment. Do not apply Command within 100 feet of the sensitive plants listed on the label or within 1,000 feet of the commercial production of vegetables or fruits and nurseries, greenhouses, towns or subdivisions.

S14. FMC-57020 (Command) may persist for more than one year in the soil. Do not rotate to sensitive crops such as small grains, corn grown for seed, alfalfa, or other forage legumes as crop injury may occur. Whitening of corn from Command carryover has been observed in Minnesota following cold or dry soil conditions, when recommended rates have been exceeded, in overlapping spray swaths, or in sprayer turn-around areas. Whitened corn plants will generally return to a normal green color within a week and corn yield should not be affected unless there was a high rate of overapplication. Calibrate your sprayer before application. Plowing with a moldboard plow reduces the potential for crop injury from residues of Command. Read the label for a listing of appropriate rotational crops.

S15. University of Minnesota research indicates that on medium to fine textured soils, rates of .50 lb/A or less of Command may not give adequate velvetleaf control. Addition of metribuzin (Lexone/Sencor) may enhance Commands effect on velvetleaf at rates of .50 lb/A or less, but more research data is needed before definite conclusions can be drawn. Depending upon the soil type, it appears that Command applied within the .50 lb/A to 1.0 lb/A range will give best results.

**Preplant Incorporated or Preemergence Applications**

S16. Several herbicides including alachlor (Lasso), chloramben (Amiben), metolachlor (Dual), and metribuzin (Sencor or Lexone) are suggested for use either preplant incorporated or preemergence. These herbicides may be left on the soil surface or incorporated with one or two tillage operations. Preplant incorporated applications of these herbicides into moist soil are more effective when there is inadequate rainfall to activate preemergence applications. However, preemergence applications provide more effective weed control when adequate rainfall does occur. If weed seedlings begin to emerge following a preemergence application due to lack of rainfall, an early harrowing, rotary hoeing, or shallow cultivation will improve weed control.

S17. Alachlor (Lasso) and metolachlor (Dual) control annual grasses, nutsedge, redroot pigweed, and nightshade. Control of other broadleaf weeds has been erratic. Preplant incorporation of alachlor or metolachlor has resulted in more consistent yellow nutsedge control than preemergence applications. Alachlor has been found to cause tumors in laboratory animals when fed to them over long periods of time. As a result, the EPA has proposed that alachlor be registered as a restricted use pesticide in 1988. The restricted use labeling will help to put this herbicide into the hands of more skilled and informed applicators.

S18. Chloramben (Amiben) controls many annual broadleaf and grass weeds on a wide range of soils when sufficient rainfall occurs before weed emergence. Excessive rainfall after application may move chloramben below the zone of weed germination and may reduce control. Soybean tolerance is good on a wide range of soils, including high pH soils. Infrequently, very heavy rainfall on coarse-textured (sandy) soils may move chloramben into contact with the germinating soybeans, resulting in stunted roots and delayed emergence.

S19. Preemergence applications of linuron (Lorox) controls annual broadleaf weeds and some grasses in soybeans. Linuron is best suited for medium-textured soils with 4 percent organic matter or less. Weed control has been inconsistent on fine-textured soils with high organic matter content. Soybean injury may occur on sandy, low organic matter soils. Potential crop injury can be decreased by using reduced rates of linuron with another herbicide (see table S1).

S20. Metribuzin (Lexone, Sencor) has provided good control of several hard-to-control broadleaf weeds, but it has marginal crop safety. Crop safety can be improved by using lower labeled tank mix rates. See the label for restrictions on various soils and soybean varieties. Soybean injury is more likely on alkaline (high pH) soils, sandy soils, where atrazine residues are present, or if used with vernolate.

**Postemergence**

S21. Acifluorfen (Blazer, Tackle) and bentazon (Basagran) alone or tank mixed are suggested for postemergence broadleaf weed control in soybeans. The herbicide or mixture used should be determined by the weed species present (see table S2). The leaf stage and size of the weeds at the time of herbicide application are critical for consistent control with either herbicide. Applications made to weeds larger than the maximum labeled leaf stage may result in inconsistent or partial control with regrowth from surviving roots and stems.

S22. Crinkling, bronzing or burning of young soybean leaves is a common response to acifluorfen (Blazer, Tackle) treatments but soybeans typically recover and develop normally. Hot, humid weather, active growth at application, and the addition of surfactants or oil concentrates increase both herbicidal effectiveness and the possibility of soybean injury. Do not apply acifluorfen to weeds under stress because effectiveness may be reduced.

S23. Bentazon (Basagran) may cause some leaf burn if applied to soybeans under stress; especially when an oil concentrate is added to improve weed control effectiveness. A split application may be necessary to control Canada thistle, yellow nutsedge, and annual broadleaf weeds that continue to germinate throughout the growing season.

S24. Weeds are much easier to control postemergence when they are young. This is especially true under adverse environmental conditions and with certain weed species, such as velvetleaf and lambsquarters. A split application of Basagran at 1 pt/A approximately two weeks after soybean planting followed by 1 pt/A 10 to 14 days later, if necessary, can prove to be quite effective and economical. Basagran is more effective if applied to young weeds. Often, removing the first flush of weeds is all that is necessary, because later weed flushes may be shaded out by the soybeans. See the label for more detailed instructions and maximum allowable weed heights and leaf stages.

S25. Herbicide additives such as surfactants, petroleum (crop) and vegetable oils, stickers, and fertilizers (28% N, 10-34-0, ammonium sulfate) often increases weed control. Misuse of additives can often result in crop injury. For example, the addition of crop oils to acifluorfen (Blazer or Tackle) increases the potential for soybean injury. This past year, labels were issued allowing the addition of 10-34-0 and 28% N to Basagran plus Blazer tank mixtures and 28% N with Basagran alone for improving the control of velvetleaf. However, addition of liquid fertilizers will result in poor control of common lambsquarters and common ragweed. If these weeds are present in addition to velvetleaf, use the oil concentrate instead of the liquid fertilizers. Do not use the oil concentrate and liquid fertilizers in the same tank mix as severe crop injury may occur. Read Table S2 and the herbicide label carefully to determine if an additive is needed and which one is recommended. Usually the herbicide rate cannot be decreased by adding an additive.

S26. Chloramben (Amiben) applied early postemergence to soybeans will control a few species of broadleaf weeds; but, for the best weed control with this herbicide, germinated weeds should be controlled with an appropriate postemergence herbicide or removed by cultivation.

S27. Diclofop (Hoelon) is labeled for postemergence annual grass and volunteer corn control in soybeans. Wild oat, giant foxtail, green foxtail, and barnyardgrass should be treated before they exceed the four-leaf stage. Yellow foxtail should be treated before it reaches the three-leaf stage for best results. The full label rate of diclofop should be used when the annual grass is at or near the maximum leaf stage for treatment. Volunteer corn should not be sprayed with diclofop until all of the corn plants have emerged. Do not tank mix diclofop with any other product or apply any other product within seven days of a diclofop application or grass control will be reduced. **Diclofop is a restricted use pesticide.**

S28. DPX-F6025 (Classic) is a new postemergence broadleaf herbicide from DuPont. Classic controls some major broadleaf weeds (see Table S2) and is most effective if applied to actively growing weeds in the 1 to 3 leaf stage. Always use a surfactant. Do not use crop oil as severe soybean injury may result. Crops other than soybeans can be extremely sensitive to low concentrations of Classic. Therefore, clean all traces of Classic from the sprayer immediately after use and prior to spraying other crops. Do not apply to soils with a pH greater than 6.8 due to carryover to sensitive crops. On soils with a pH of 6.8 or less wheat and barley can be planted 3 months after application of Classic; there is a 9 month restriction before planting corn.

S29. Fluazifop (Fusilade) and sethoxydim (Poast) are postemergence chemicals for annual and perennial grass control in soybeans. Soybeans have good tolerance. Neither chemical controls broadleaf weeds. An oil concentrate is used with the spray to improve performance. Tank mixtures with bentazon (Basagran) and acifluorfen (Blazer) provide control of many broadleaf weeds also, but effectiveness of sethoxydim and fluazifop on grasses may be reduced. See the appropriate labels and paragraph S30 for further information on these tank mixes.

S30. Tank mixtures of fluazifop (Fusilade) and sethoxydim (Poast) with bentazon (Basagran) and/or aciflurofen (Blazer) may result in reduced grass weed control. Therefore, when tank mixing one of these grass herbicides with Basagran or Blazer use a grass herbicide rate that is 50% higher than would be used when the grass herbicide is used alone. Another option is to apply postemergence broadleaf and grass herbicides separately in sequential applications. The table below lists the minimum waiting period between the first and second herbicide application. With broadleaf tank mixtures, the herbicide with the longest waiting period should be used. In most instances, broadleaf herbicides should be applied first because they generally need to be applied to smaller (younger) weeds to be effective.

| Herbicide Applied First | Herbicide Applied Second | Minimum Waiting Period |
|---|---|---|
| Basagran | Poast | 24 hours |
| Basagran | Fusilade | 24 hours |
| Blazer | Poast | 7 days |
| Blazer | Fusilade | after new leaf growth resumes |
| Fusilade | Basagran | 24 hours |
| Fusilade | Blazer | 3 to 5 days* |
| Poast | Basagran | 24 hours |
| Poast | Blazer | 24 hours |

*Wait a minimum of 3 days when treating annual grasses and at least 5 days when treating perennial grasses.

S31. 2,4-DB amine (Butoxone, Butyrac 200) is labeled for postemergence control of common cocklebur in soybeans. Weed control is less satisfactory and the potential for crop injury greater when 2,4-DB is used than when other postemergence broadleaf herbicides are used. When using 2,4-DB at or above the .7 pt/A rate it must be applied as a post-directed spray. Do not allow spray to contact the soybean growing point as excessive crop injury will result. A combination of 2,4-DB with naptalam (Rescue) can be applied as a broadcast application to larger soybeans after first bloom when competition from cocklebur, giant ragweed, sunflower and marshelder is severe enough to reduce competition. Some soybean leaf injury and stunting should be expected.

Table S1. Summary of herbicides for use in soybeans.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **NO-TILL or MINIMUM TILL** | | | |
| **glyphosate** (Roundup 3S) | .19 to 3 (.5 to 8 pts) | Apply prior to soybean emergence. At lower rates, controls emerged annual grass and broadleaf weeds. At higher rates, suppresses emerged perennial weeds. A nonselective translocated herbicide with no soil activity so commonly combined with residual herbicides. | S8 |
| Labeled mixtures | | | |
| alachlor (Lasso or Bronco) | 2.5 to 4 | Adds preemergence control of annual grass and a few broadleaf weeds. | |
| alachlor + linuron (Lorox) | 2.5 to 4 + .5 to 1.5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| alachlor + metribuzin (Lexone, Sencor) | 2.5 to 4 + .25 to .75 | Adds preemergence control of annual grass and broadleaf weeds. | |
| Mixtures listed on other labels | | | |
| chloramben (Amiben) | 2 to 3 | Adds preemergence weed control. Use any labeled preemergence chloramben tank mix. | |
| metolachlor (Dual) + linuron | 1.5 to 2.5 + .5 to 1.5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| metolachlor + metribuzin | 1.5 to 2.5 + .25 to .5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| chloramben + metolachlor | 2 to 3 + 1.5 to 2.5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| chloramben + alachlor | 2 to 3 + 1.5 to 3 | Adds preemergence control of annual grass and broadleaf weeds. | |
| **paraquat** (Gramoxone Super 1.5 S) | .25 to 1 (1.3 to 5.3 pts) | Apply prior to soybean emergence. Controls emerged annual grass and broadleaf weeds. A nonselective contact herbicide with no soil activity so commonly combined with residual herbicides. Apply with a .5 to 1 pt nonionic spreader per 100 gal of spray solution. **A restricted use herbicide.** | S9 |
| Labeled mixtures | | | |
| linuron (Lorox) | .5 to 1.5 | Adds preemergence control of broadleaf weeds. | |
| metribuzin (Lexone, Sencor) | .38 to 1 | Adds preemergence control of broadleaf weeds. | |
| alachlor (Lasso) + linuron | 2 to 3 + .5 to 1.5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| alachlor + metribuzin | 2 to 3 + .25 to .5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| metolachlor (Dual) + linuron | 1.5 to 2.5 + .5 to 1.5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| metolachlor + metribuzin | 1.5 to 2.5 + .25 to .5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| Mixtures listed on other labels | | | |
| chloramben (Amiben) | 2 to 3 | Adds preemergence weed control. Use any labeled preemergence chloramben tank mix. | |
| chloramben + alachlor | 2 to 3 + 1.5 to 3 | Adds preemergence control of annual grass and broadleaf weeds. | |
| chloramben + metolachlor | 2 to 3 + 1.5 to 2.5 | Adds preemergence control of annual grass and broadleaf weeds. | |
| **PREPLANT INCORPORATED** | | | |
| **ethalfluralin** (Sonalan 3 EC) | .56 to 1.31 (1.5 to 3.5 pts) | Controls annual grasses and some broadleaf weeds. At 3 to 3.5 pts/A and two incorporation passes, partial control of eastern black nightshade is achieved. | S10, S11 S12 |

**Table S1. Continued.**

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtures | | | |
| alachlor (Lasso) | 2.5 to 4 | Adds control of nightshades and yellow nutsedge. | |
| chloramben (Amiben) | 2 to 3 | Adds control of broadleaf weeds. | |
| FMC-57020 (Command) | .38 to .75 | Adds control of velvetleaf. | S13, S14, S15 |
| metolachlor (Dual) | 1.5 to 3 | Adds control of nightshades and yellow nutsedge. | |
| metribuzin (Lexone, Sencor) | .25 to .5 | Adds control of wild mustard and other broadleaf weeds. | |
| vernolate (Vernam) | 2.0 to 2.6 | Adds control of yellow nutsedge. | |
| alachlor + metribuzin | 2.5 to 4 + .25 to .5 | Controls additional broadleaf weeds. | |
| FMC-57020 + metribuzin | .25 to .56 + .17 to .5 | Controls additional broadleaf weeds and improves grass control. | S13, S14, S15 |
| metolachlor + metribuzin | 1.5 to 3 + .25 to .5 | Controls additional broadleaf weeds. | |
| **FMC-57020** (Command 4 EC) | .75 to 1.0 (1.5 to 2.0 pts) | Controls some annual grass and broadleaf weeds, especially good on velvetleaf. **Apply preplant incorporated only.** See reference section for application and crop rotation restrictions. | S10, S11 S13, S14 |
| Labeled mixture | | | |
| metribuzin (Lexone, Sencor) | .19 to .38 | Adds control of pigweed, wild mustard and other broadleaf weeds and improves grass control. | S15 |
| **pendimethalin** (Prowl 4 EC) | .5 to 1.5 (1 to 3 pts) | Controls annual grass and some broadleaf weeds. **Apply preplant incorporated only.** | S10, S11, S12 |
| Labeled mixtures | | | |
| alachlor (Lasso) | 2.5 to 4 | Improves grass control and adds control of nightshades and yellow nutsedge. | |
| chloramben (Amiben) | 2 | Adds control of smartweeds, velvetleaf and common ragweed. | |
| metolachlor (Dual) | 1.5 to 3 | Improves control of grasses and adds control of nightshades and yellow nutsedge. | |
| metribuzin (Lexone, Sencor) | .5 to .75 | Controls additional broadleaf weeds. | |
| chloramben + metribuzin | 1.5 to 2 + .37 to .55 | Controls additional broadleaf weeds. | |
| **trifluralin** (Treflan 4 MTF) (Treflan Pro 5) (Treflan TR-10) | .5 to 1 (1 to 2 pts) (.8 to 1.6 pts) (5 to 10 lbs) | Controls annual grass and some broadleaf weeds. Apply preplant incorporated in the fall or spring. Do not exceed recommended rates for the soil type or carryover may injure sensitive crops the following year. | S10, S11, S12 |
| Labeled mixtures | | | |
| alachlor (Lasso) | 2.5 to 4 | Adds control of nightshades and yellow nutsedge. Preemergence overlay cleared. | |
| chloramben (Amiben) | 2 to 3 | Adds control of broadleaf weeds. Preemergence overlay cleared. | |
| FMC-57020 (Command) | .38 to .75 | Adds control of velvetleaf. | S13, S14, S15 |
| metolachlor (Dual) | 1.5 to 3 | Adds control of nightshades and yellow nutsedge. Preemergence overlay cleared. | |
| metribuzin (Lexone, Sencor) | .25 to .5 | Adds control of wild mustard and other broadleaf weeds. | |
| chloramben + metribuzin | 1.5 to 2.5 + .25 to .38 | Controls additional broadleaf weeds. Preemergence overlay cleared. | |
| FMC-57020 + metribuzin | .25 to .56 + .17 to .5 | Controls additional broadleaf weeds and improves grass control. | S13, S14, S15 |

Table S1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **vernolate** | 2 to 3 | Controls annual grasses, some broadleaf weeds and yellow nutsedge. | S10, S11 |
| (Vernam 7 EC) | (2.3 to 3.5 pts) | **Incorporate immediately after application.** The Reward formulation | |
| (Vernam 10 G) | (20 to 30 lbs) | contains an extender to increase the soil persistence of vernolate. Reward | |
| (Reward 6 EC) | (2.7 to 4 pts) | or Vernam may be applied and incorporated after planting. | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 1 to 2 | Adds control of nightshades. | |
| chloramben (Amiben) | 1.5 | Adds control of many broadleaf weeds. | |
| pendimethalin (Prowl) | .38 to .75 | Adds control of kochia and lambsquarters. | |
| trifluralin (Treflan) | .5 to 1 | Adds control of kochia and lambsquarters and improves annual grass control. | |
| trifluralin + metribuzin | .5 + .25 to .38 | Adds control of many broadleaf weeds and improves annual grass control. | |
| **PREPLANT or PREEMERGENCE** | | | |
| **alachlor** | 1.5 to 4 | Controls annual grass and some broadleaf weeds including nightshade. | S16, S17 |
| (Lasso 4 EC) | (3 to 8 pts) | Weak on wild mustard. Cleared postemergence but less effective on emerged | |
| (Lasso II) | (16 to 26 lbs) | weeds. Alachlor will probably be a restricted use herbicide in 1988. | |
| (Lasso 4 MT) | (3 to 8 pts) | | |
| Labeled mixtures | | | |
| chloramben (Amiben) | 2 | Adds control of many broadleaf weeds. | |
| linuron (Lorox) | .5 to 1.5 | Do not incorporate. Provides additional broadleaf weed control. | |
| metribuzin (Lexone,Sencor) | .25 to .5 | Adds control of many broadleaf weeds. | |
| trifluralin (Treflan) | .5 | Adds control of kochia and lambsquarters. Preplant incorporated only. | |
| chloramben + metribuzin | .75 to 3 + .25 to .5 | Adds control of many broadleaf weeds. | |
| **chloramben** | 1.8 to 3 | Controls annual grass and broadleaf weeds but more effective on broadleafs. | S16, S18 |
| (Amiben 2S) | (8 to 12 pts) | Cleared postemergence but less effective on emerged weeds. Weak on wild | |
| (Amiben 75 DS) | (2.4 to 3.6 lbs) | mustard. | |
| (Amiben 10 G) | (20 to 30 lbs) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 1.5 to 3 | Improves grass, nutsedge and nightshade control. | |
| ethalfluralin (Sonalan) | .5 to 1.12 | Preplant incorporate or use Amiben as a preemergence overlay. Improves grass control. | |
| linuron (Lorox) | .33 to 1.5 | Preemergence only. Improves grass and broadleaf weed control. | |
| metolachlor (Dual) | 1.5 to 2.5 | Improves grass, nutsedge and nightshade control. | |
| metribuzin (Lexone,Sencor) | .25 to .5 | Improves broadleaf weed control, especially wild mustard. | |
| pendimethalin (Prowl) | .75 to 1.25 | Preplant incorporated only. Improves grass control. | |

Table S1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| trifluralin (Treflan) | .5 to 1 | Preplant incorporated only. Improves grass control. | |
| vernolate (Vernam, Reward) | 2.7 to 4 | Preplant incorporated. Improves grass and velvetleaf control. | |
| alachlor + linuron | 1.5 to 3 + .33 to 1.5 | Preemergence only. Improves grass, nutsedge, nightshade and mustard control. | |
| alachlor + metribuzin | 1.5 to 3 + .25 to .5 | Improves grass, nutsedge, nightshade and mustard control. | |
| metolachlor + linuron | 1.5 to 3 + .33 to 1.5 | Preemergence only. Improves grass, nutsedge, nightshade and mustard control. | |
| metolachlor + metribuzin | .75 to 1.5 + .25 to .5 | Improves grass, nutsedge, nightshade and mustard control. | |
| pendimethalin + metribuzin | .75 to 1.5 + .25 to .5 | Preplant incorporated only. Improves grass and mustard control. | |
| trifluralin + metribuzin | .5 to 1 + .25 to .5 | Preplant incorporated only. Improves grass and mustard control. | |
| **linuron** | .17 to 2.5 | Use in preemergence mixtures to improve broadleaf weed control. Ineffective if incorporated. If emerged, soybeans will be severely injured. Do not use on sandy soils with less than 0.5% organic matter. Directed postemergence for small broadleafs. | S19 |
| (Lorox 50 WP, DF) | (.33 to 5 lbs) | | |
| (Lorox 4L) | (.34 to 5 pts) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | .75 to 3 | Improves grass, nutsedge and nightshade control. | |
| chloramben (Amiben) | 1.5 to 2.5 | Improves overall grass and broadleaf weed control. | |
| metolachlor (Dual) | 1.25 to 2.5 | Improves grass, nutsedge and nightshade control. | |
| pendimethalin (Prowl) | .5 to 1.3 | Improves grass control. Apply pendimethalin preplant and linuron preemergence. | |
| 2,4-DB (Butyrac 200, Butoxone) | .2 | Directed spray to soybeans over 8 inches tall to control 1- to 3-inch weeds. | |
| alachlor + metribuzin (Lexone) | .75 to 3 + .12 to .33 | Improves grass, nutsedge and broadleaf weed control. | |
| metolachlor + metribuzin | 1.25 to 2.5 + .12 to .33 | Improves grass, nutsedge and broadleaf weed control. | |
| **metolachlor** | 1.5 to 4 | Controls annual grasses and some broadleafs. Apply preplant incorporated or preemergence. Cleared early preplant for no-till and minimum till, where it can be applied as a split application treatment. | S16, S17 |
| (Dual 8 EC) | (1.5 to 4 pts) | | |
| (Dual 25 G) | (6 to 16 lbs) | | |
| Labeled mixtures | | | |
| chloramben (Amiben) | 1.8 to 2.7 | Adds control of many broadleaf weeds. | |
| linuron (Lorox) | .5 to 1.5 | Preemergence only. Adds control of broadleaf weeds. | |
| metribuzin (Lexone,Sencor) | .25 to .5 | Adds control of many broadleaf weeds. | |
| **metribuzin** | .25 to .88 | Controls many broadleaf weeds including wild mustard. Apply early preplant, preplant incorporated or preemergence. Use in mixtures with grass herbicides. Soybean tolerance is marginal. In early preplant application, a second preemergence application can be used to extend weed control. | S16, S20 |
| (Lexone or Sencor 4L) | (.5 to 1.75 pts) | | |
| (Lexone or Sencor 75 DF) | (.3 to 1.2 lbs) | | |
| Labeled mixtures | | | |
| alachlor (Lasso) | 2 to 3 | Improves grass, nutsedge and nightshade control. | |
| ethalfluralin (Sonalan) | .56 to 1.12 | Preplant incorporated only. Improves grass control. | |
| metolachlor (Dual) | 1.25 to 2.5 | Improves grass, nutsedge and nightshade control. | |
| pendimethalin (Prowl) | .75 to 1 | Preplant incorporate to minimize soybean injury. Improves grass control. | |

Table S1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| trifluralin (Treflan) | .5 to 1 | Preplant incorporated only. Improves grass control. | |
| FMC-57020 (Command) + grass herbicide | .25 to .38 + .5 to 3 | Preplant incorporated only. Use any of the five grass herbicides listed above at their recommended use rate. See references for more details. | S10, S11, S13, S15 |
| chloramben (Amiben) | 1.5 to 2.5 | Improves grass and nightshade control. | |
| alachlor + linuron (Lorox) | .75 to 2 + .17 to 1 | Improves grass and adds some broadleaf control. | |
| metolachlor + linuron | 1.25 to 2.5 + .17 to 1 | Improves grass and adds some broadleaf control. | |
| Package mixture | | | |
| metribuzin + metolachlor (Turbo 8 EC) | 1.5 to 3.5 | Turbo contains 1.45 and 6.55 lb/gal of metribuzin and metolachlor, respectively. Can be tank mixed with Command. | S13, S15 |
| **POSTEMERGENCE** | | | |
| **acifluorfen** | .25 to .75 | Controls many broadleaf weeds. For best results apply to weeds in the 2 to 4 leaf stage and actively growing. Contact burn of soybean leaves frequently occurs but recovery is rapid. Surfactant is needed for maximum effectiveness. | S21, S22 |
| (Blazer 2S) | (1 to 3 pts) | | |
| (Tackle 2S) | (1.5 to 3 pts) | | |
| Labeled mixtures (Blazer) | | | |
| bentazon (Basagran) | .5 to .75 | Improves broadleaf weed control. Adding liquid fertilizer (10-34-0 or 28% N) improves velvetleaf control. | S25 |
| chloramben (Amiben) | 2.5 to 3 | Provides residual activity for later germinating weeds. | |
| fluazifop (Fusilade) | .13 to .25 | Adds grass and corn control. Some antagonism in tank mixes. | S30 |
| sethoxydim (Poast) | .23 to .38 | Adds annual grass and corn control. Use 50% greater rates of sethoxydim in tank mixes. | S30 |
| bentazon + sethoxydim | .5 to .75 + .23 to .38 | Adds annual grass and corn control. Improves broadleaf weed control. Use 50% greater rates of sethoxydim in tank mixes. | S30 |
| 2,4-DB (Butyrac 200, Butoxone) | .03 | Improves control of larger cocklebur, pigweed and ragweed. | |
| Labeled mixtures (Tackle) | | | |
| bentazon (Basagran) | .5 to .75 | Improves broadleaf weed control. Addition of liquid fertilizer is not labeled at this time. | |
| 2,4-DB (Butyrac 200, Butoxone) | .03 | Improves control of larger cocklebur, pigweed and ragweed. | |
| **barban** (Carbyne 2 EC) | .38 (1.5 pt) | Controls wild oats only. Apply when wild oats is in 2-leaf stage and within 30 days of crop emergence. Wild oats usually develop to the 2-leaf stage 9 days after emergence. | |
| **bentazon** (Basagran 4S) | .75 to 1 (1.5 to 2 pt) | Controls many broadleaf weeds, nutsedge and Canada thistle. For best results apply to weeds in the 2 to 4 leaf stage and actively growing. Add 1 qt/A of oil concentrate for maximum effectiveness. May be applied in a split application. | S21, S23, S24 |

Table S1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| Labeled mixtuers | | | |
| acifluorfen (Blazer) | .125 to .5 | Improves control of nightshade, pigweeds and common ragweed. Soybean leaf burn occurs. Addition of liquid fertilizer (28% N) improves velvetleaf control. | S25 |
| sethoxydim (Poast) | .3 to .4 | Adds annual grass and corn control. Use 50% higher sethoxydim rate in tank mix. | S30 |
| acifluorfen + sethoxydim | .25 + .3 | Improves control of broadleafs. Adds control of annual grasses and corn. Use 50% higher sethoxydim rate in tank mix. | S30 |
| **chloramben** | 3 | Must add crop oil. Use after a soil-applied grass herbicide. Postemergence suppression or control of pigweed, common ragweed, velvetleaf and Pennsylvania smartweed plus residual preemergence activity. | S26 |
| (Amiben 2S) | (.12 pt) | | |
| (Amiben 10 G) | (30 lbs) | | |
| (Amiben 75 DS) | (3.6 lbs) | | |
| Labeled mixtures | | | |
| acifluorfen (Blazer) | .38 to .5 | Adds control of many emerged broadleaf weeds plus residual preemergence activity. | |
| naptalam (Alanap) | 1 to 1.5 | May cause temporary stunting of soybeans. Apply to 3 to 6 trifoliolate soybeans. | |
| 2,4-DB (Butyrac 200) | .03 | May cause temporary twisting of soybean leaves and stems. Apply to 2 to 4 trifoliolate soybeans. | |
| **diclofop** (Hoelon 3 EC) | .75 to 1.25 (2 to 3.3 pts) | Controls many annual grasses and volunteer corn. Apply to grasses in the 1 to 4 leaf stage. **A restricted use herbicide.** | S27 |
| **DPX-F6025** (Classic 25 DG) | .008 to .010 (.5 to .75 oz) | Controls some major broadleaf weeds. For best results apply to actively growing weeds in the 1 to 3 leaf stage. Always use a surfactant. Do not use oil concentrate. **Do not apply to soils with a pH of 6.8 or greater.** | S28 |
| Labeled mixture | | | |
| acifluorfen (Blazer) | .25 to .75 | Improves control of nightshades. | |
| **fluazifop** (Fusilade 2000 1EC) | .09 to .19 (.75 to 1.5 pts) | Controls annual grasses, corn and quackgrass. For best results apply when grasses are 2 to 4 leaf and actively growing. Quackgrass may require two applications. Always add a surfactant or crop oil concentrate. | S29 |
| Labeled mixtures | | | |
| acifluorfen (Blazer) | .25 to .75 | Adds broadleaf weed control. Add a surfactant. Sequential or tank mix. | S30 |
| bentazon (Basagran) | .75 to 1 | Adds broadleaf weed control. Add an oil concentrate. Sequential or tank mix. | S30 |
| **paraquat** (Gramoxone Super 1.5 S) | .12 to .25 (.6 to 1.3 pts) | Soybean harvest aid. Desiccates soybeans, grasses and broadleaf weeds prior to harvest. Apply when at least 65% of the seed pods have reached a mature brown color or when seed moisture is 30% or less. **Restricted use herbicide.** | |

Table S1. Continued.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **sethoxydim** (Poast 1.5 EC) | .09 to .5 (.5 to 2.5 pts) | Controls annual grasses and corn and suppresses quackgrass. For best results apply when grasses are 2 to 6 inches and actively growing. Quackgrass may require two applications or addition of ammonium sulfate. Always add an oil concentrate. | S29 |
| Labeled mixtures | | | |
| bentazon (Basagran) | .75 to 1 | Adds broadleaf weed control. Add an oil concentrate. Sequential or tank mix. | S30 |
| bentazon + acifluorfen (Blazer) | .75 to 1 + .12 to .25 | Adds broadleaf weed control. Add an oil concentrate. Sequential or tank mix. | S30 |
| **2,4-DB** (Butyrac 200 2L) (Butoxone 2L) | .18 to .4 (.7 to .9 pt) (.9 to 1.6 pts) | Mainly for cocklebur control. Apply as a post-directed spray to soybeans at least 8 inches tall. Cocklebur should not exceed 3 inches in height or other weeds 2 inches in height. | S31 |
| Labeled mixture | | | |
| naptalam (Alanap) | 1 to 1.5 | Tank mix .03 to .06 lb/A of 2,4-DB with naptalam. Apply broadcast to soybeans after first blooms appear to suppress cocklebur, giant ragweed, sunflower and marshelder. Some soybean injury should be expected. A non-ionic surfactant or oil concentrate is required. | S31 |
| Package mixtures | | | |
| 2,4-DB + naptalam (Rescue 2.06 EC) | .15 | | |

*Reference number indicates appropriate paragraph in the narrative.

Table S2. Effectiveness of herbicides on major weeds in soybeans[1,2]

| | | Grasses | | | | | | Broadleafs | | | | | | | | | | | | | Perennials | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soybean tolerance | Barnyardgrass | Woolly cupgrass | Giant and green foxtail | Yellow foxtail | Wild proso millet | Sandbur | Cocklebur | Kochia | Lambsquarters | Venice mallow | Mustard | Eastern black nightshade | Hairy nightshade | Pigweed | Common ragweed | Giant ragweed | Smartweed | Wild sunflower | Velvetleaf | Canada thistle | Nutsedge | Quackgrass |
| **Preplant incorporated** | | | | | | | | | | | | | | | | | | | | | | | |
| alachlor (Lasso) . . . . . . . . | G | G | G | G | G | F | F | P | P | F/P | P | P | F | F | G | P | P | P | P | P | N | G | N |
| chloramben (Amiben). . . . . . . | G | G | G | G | G | F | P | P | G | G | G | F | F | F | G | G | F | G | P | F | N | P | N |
| ethalfluralin (Sonalan). . . . | F/G | G | G | G | G | F | G | N | G | F/G | P | N | F | P | G | N | N | P | N | N | N | N | P |
| FMC-57020 (Command). . . . . . . | G | G | F | G | F | F | - | F | - | F/G | G | P | P | - | P | F | P | F/G | P | G | - | N | - |
| metolachlor (Dual) . . . . . . . | G | G | G | G | G | F | F | N | P | F/P | P | P | F | F | G | P | P | P | P | P | N | G | N |
| metribuzin (Sencor, Lexone). . | F | F | P | F | F | P | P | F | G | G | G | G | P | P | G | G | P | G | F | G | P | P | P |
| pendimethalin (Prowl). . . . . | F/G | G | G | G | G | F | G | N | G | F/G | P | N | P | P | G | N | N | F | N | F | N | N | P |
| trifluralin (Treflan). . . . . | F/G | G | G | G | G | F | G | N | G | F/G | P | N | P | P | G | N | N | P | N | N | N | N | P |
| vernolate (Vernam, Reward) . . | F | G | F/G | G | G | F | G | P | - | F | G | F | P | P | G | P | P | P | P | F | N | G | F |
| **Preemergence** | | | | | | | | | | | | | | | | | | | | | | | |
| alachlor (Lasso) . . . . . . . . | G | G | G | G | G | F | F | N | P | F/P | P | P | G | G | G | P | P | P | P | P | N | F | N |
| chloramben (Amiben). . . . . . . | G | F/G | G | F/G | F/G | F | P | P | G | G | G | F | G | G | G | G | F | G | P | F | N | P | N |
| linuron (Lorox). . . . . . . . . | F | F | P | F | F | P | P | P | F | G | G | G | P | - | G | G | F | F | P | F | P | P | N |
| metolachlor (Dual) . . . . . . . | G | G | G | G | G | F | F | N | P | F/P | P | P | G | F | G | P | P | P | P | P | N | F | N |
| metribuzin (Sencor, Lexone). . | F | F | P | F | F | P | P | F | G | G | G | G | P | P | G | G | F | G | F | F | P | P | P |
| **Postemergence** | | | | | | | | | | | | | | | | | | | | | | | |
| acifluorfen (Blazer, Tackle) . | F | P | P | P | P | P | P | F | - | P | F | G | G | F | G | G | G | G | F/G | P | P | P | N |
| bentazon (Basagran). . . . . . . | G | N | N | N | N | N | P | G | F | F | G | G | F | F | P | G | F | G | G | G | G* | G* | N |
| diclofop (Hoelon). . . . . . . . | G | G | P | G | F | P | P | N | N | N | N | N | N | N | N | N | N | N | N | N | N | P | N |
| DPX-F6025 (Classic). . . . . . | F/G | P | P | P | P | P | P | G | P | P | F | G | P | - | G | G | F/G | G | G | F | - | G | N |
| fluazifop (Fusilade 2000). . . | G | G | G | G | G | G | G | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | G |
| naptalam + 2,4-DB (Rescue) . . | F/P | P | P | P | P | P | P | F | P | - | - | - | - | - | - | P | F | - | F | - | P | P | N |
| sethoxydim (Poast) . . . . . . . | G | G | G | G | G | G | G | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | F |
| 2,4-DB (Butoxone, Butyrac 200) | P | N | N | N | N | N | N | F | - | P | P | P | P | - | P | P | F | P | P | P | P | N | N |

[1]G = good; F = fair; P = poor; N = no control; - = insufficient information.
[2]This chart should be used only as a guide. Ratings of chemicals may be higher or lower than indicated depending on soil characteristics, managerial factors, environmental variables, and rates applied.
*Degree of perennial weed control is often a result of repeated application.

**SUGARBEETS**

SU1. Sugarbeets are poor competitors with weeds from emergence until the sugarbeet leaves shade the ground. Emerging sugarbeets are small and lack vigor and sugarbeets take approximately two months to shade the ground. Thus, weeds have a long period to become established and compete with sugarbeets. Sugarbeets are relatively short even after they shade the ground so many weeds that become established in a sugarbeet field prior to ground shading will become taller than the sugarbeets, shade the sugarbeets, and cause severe yield losses. To avoid yield loss from weed competition, weeds should be totally controlled by four weeks after sugarbeet emergence and weed control should be maintained throughout the season.

SU2. A combination of cultural, chemical, and mechanical weed control methods should be used to maximize weed control in sugarbeets. Some weed species such as Canada thistle, kochia, common mallow, common milkweed, cocklebur, and velvetleaf are difficult or impossible to control selectively in sugarbeets with herbicides. These weeds in particular, and all weeds in general, should be effectively controlled in other crops in the rotation. Spot spraying or hand weeding small areas should be used to prevent establishment of problem weeds. Sugarbeets should not be planted on fields badly infested with problem weeds.

SU3. Cultivation with a row crop cultivator is a universal and essential weed control method in sugarbeets. Also, the rotary hoe or spring tine harrow can be used to remove small weeds from well rooted sugarbeets. Hand weeding is still an important method of weed control in sugarbeets with 64% of the acres in Minnesota and Eastern North Dakota receiving some hand weeding in 1985. The decision on using hand weeding or other methods of weed control should be based on expected economic returns. Generally herbicides will be more cost effective than hand weeding in moderate to heavy weed densities. Hand weeding may be more cost effective in low weed densities, especially if the weeds are expected to be difficult to control with herbicides.

**Preemergence Contact or Tillage Substitution Herbicides**

SU4. Paraquat (Gramoxone), a nonselective herbicide, can be used at 0.5 lb/A as a substitute for tillage. Paraquat may be applied before or after planting until just before crop emergence. Apply paraquat in 5 to 10 gpa of water by air or in 20 to 60 gpa of water by ground. Add Ortho X-77 to the spray solution at 0.5 to 1 pint/100 gallons. Paraquat can be used on land intended for barley, corn, potatoes, soybeans, sugarbeets, sunflower and wheat. Paraquat is a restricted use pesticide because it is very toxic so avoid contact with the skin; small amounts could be fatal if swallowed.

SU5. Glyphosate (Roundup) can be applied before sugarbeets emerge to emerged weeds at 0.19 to 0.75 lb/A (0.5 to 2 pt/A). Use the higher rate on larger weeds, more resistant weeds, or if the plants are under moisture stress. When low rates of glyphosate are used, apply in 3 to 10 gallons of water per acre by ground or in 3 to 5 gpa by air. Delay tillage for at least 3 days after treatment.

SU6. **Preemergence Herbicides:** Good weed control with preemergence herbicides requires rainfall after application. Herbicides which are incorporated into the soil surface usually require less rainfall after application for effective weed control than unincorporated herbicides. Weeds emerging through a preemergence herbicide treatment may be controlled by rotary hoeing or harrowing without reducing the effect of the herbicide unless the harrow or rotary hoe removes the herbicide from a treated band.

**Incorporation of Herbicides**

SU7. Cycloate and EPTC should be incorporated immediately after application regardless of whether the liquid or granular formulation is used. Ethofumesate, diethatyl, pyrazon, and TCA may be used preemergence but incorporation usually improves weed control especially on fine-textured soils or with limited rainfall after application. Incorporation may reduce weed control if heavy rains follow application and incorporation may increase sugarbeet injury compared to surface application. Experience indicates that lack of rainfall is more common than excess rainfall following planting. TCA should not be incorporated on lighter soils where sugarbeet injury from TCA is a concern.

SU8. EPTC (Eptam) preplant incorporated in the spring at 2 to 3 lb/A or fall applied at 4 to 4.5 lb/A gives good control of annual grasses and certain broadleaf weeds. EPTC sometimes causes sugarbeet stand reduction and temporary stunting. However, no yield reduction will result if enough sugarbeets remain to obtain an adquate plant population after thinning. EPTC should be used with extreme caution on sugarbeets grown in sandy loam or coarser-textured soils with low organic matter levels because a safe EPTC rate is difficult to predict on such soils.

SU9. Cycloate (Ro-Neet) spring applied at 3 to 4 lb/A or fall applied at 4 lb/A gives weed control similar to EPTC. EPTC tends to give better weed control than cycloate on fine-textured, high organic matter soils or under relatively dry conditions while cycloate gives better control than EPTC when spring rainfall is adequate to excessive. Cycloate causes less sugarbeet injury than EPTC and is thus safer for use on more coarse textured, low organic matter soils. Cycloate should be incorporated immediately and thoroughly the same as EPTC. Research in North Dakota and Minnesota has shown that a mixture of EPTC and cycloate in the fall or spring gave effective weed control with less sugarbeet injury than EPTC alone and at a lower cost than cycloate alone. Rates of application for the mixture must be adjusted for soil texture and organic matter. Effective rates in research have been 1 to 2 lb/A of EPTC plus 2 to 2.5 lb/A of cycloate in the spring and from 2 to 3 lb/A of EPTC plus 2 to 2.5 lb/A of cycloate in the fall.

SU10. TCA at 4.7 to 7.1 lb/A gives good control of green and yellow foxtail. Research has indicated that shallow incorporation generally will not reduce the weed control from TCA and under low rainfall conditions will improve weed control. Incorporation may reduce grass control from TCA if excessive rain follows application especially on the more coarse textured soils. TCA should not be incorporated on low organic matter, coarse textured soils where TCA injury to sugarbeets is a concern.

SU11. Pyrazon (Pyramin) spring applied at 3.1 to 7.6 lb/A controls most broadleaf weeds. Pyrazon has been less effective on soils with more than 5% organic matter. Weed control from pyrazon generally increases as soil organic matter content decreases. Shallow incorporation generally improves weed control from pyrazon. High amounts of rainfall after application improves weed control from pryazon.

SU12. Ethofumesate (Nortron) at 2 to 3.75 lb/A gives good control of several broadleaf and grassy weeds, is especially effective on redroot pigweed, but is weak on yellow foxtail. Ethofumesate generally gives less sugarbeet injury than EPTC (Eptam) especially on more coarse textured, low organic matter soils. Ethofumesate may be applied preemergence but incorporation generally improved weed control in tests in North Dakota and Minnesota. Preemergence applications of ethofumsate will give good weed control when relatively large amounts of rain follow application. The exact amount of rain needed is not known but field observations indicate that at least 1 inch of rain is needed to give best results from preemergence ethofumesate. Coarse textured, low organic matter soils require less rain for activation than fine textured, high organic matter soils. Ethofumesate often has a residue the year following use on sugarbeets. Crops most likely to be damaged by ethofumesate residue are wheat, barley, and oats. Moldboard plowing usually eliminates carryover injury. Ethofumesate should be applied in a band to reduce cost and reduce carryover.

SU13. Diethatyl (Antor) spring applied at 4 to 6 lb/A gives good to excellent control of redroot pigweed and prostrate pigweed. Diethatyl generally gives less sugarbeet injury than EPTC (Eptam) especially on coarse textured, low organic matter soils. Diethatyl may be applied preemergence but incorporation generally improved weed control in tests in North Dakota and Minnesota. Preemergence diethatyl will give good weed control is adequate rain follows application. Diethatyl needs amounts of rain similar to ethofumesate as discussed in the previous paragraph.

**Postemergence Herbicides**

SU14. Desmedipham (Betanex) and desmedipham + phenmedipham (Betamix) are postemergence herbicides for the control of annual broadleaf weeds. To avoid possible sugarbeet injury from desmedipham and phenmedipham, several precautions should be observed: 1) The sugarbeets should have at least four true leaves before treatment with full rates. 2) Use no more than 1 lb/A following EPTC or TCA. 3) Start application late in the afternoon or early in the evening so cool temperatures follow application. 4) Do not apply if the highest temperature on the day of application exceeds 85 F. 5) Set the desired band width near the top of the sugarbeets so that the beets rather than the ground receive the proper rate. Desmedipham or desmedipham + phenmedipham slightly better on wild mustard and desmedipham + phenmedipham slightly better on common lambsquarters. Desmedipham gives clearly superior control of redroot and prostrate pigweed while desmedipham + phenmedipham is better on kochia and wild buckwheat. Split application with reduced rates has reduced sugarbeet injury and increased weed control compared to a single full dose application. Risk of sugarbeet injury is reduced by starting application in late afternoon so cooler temperatures follow application.

SU15. Endothall (Herbicide 273) at 0.75 to 1.5 lb/A gives good control of wild buckwheat, smartweed, and marshelder. Good control of volunteer sunflower was obtained from H-273 in research when the volunteer sunflower was growing in good soil moisture. Sugarbeets should have 4 to 6 leaves before application and should not be treated later than 40 days after emergence. Temperatures should be 60 to 80 F at application. Weed control may be poor when weeds are under even slight drought stress.

SU16. Sethoxydim (Poast) at 0.1 to 0.5 lb/A plus an oil additive will control annual and suppress perennial grasses. An oil additive must be used for consistently good grass control. Tank mixing sethoxydim (Poast) plus oil additive with desmedipham, phenmedipham, or endothall often gives less grass control, especially of wild oats.

SU17. **Combinations of postemergence herbicides** give more broad spectrum and greater total weed control compared to individual treatments. The risk of sugarbeet injury also increases with combinations so combinations should be used with caution. Ethofumesate (Nortron) in combination with desmedipham and desmedipham + phenmedipham has given improved weed control compared to desmedipham or desmedipham + phenmedipham used alone. Dalapon mixed with desmedipham or desmedipham + phenmedipham has given improved broadleaf weed control compared to desmedipham or desmedipham + phenmedipham alone. This combination increases the risk of sugarbeet injury. Endothall (H-273) has been used at 0.25 to 0.5 lb/A in combination with desmedipham or desmedipham + phenmedipham to give improved control of wild buckwheat and cocklebur compared to desmedipham or desmedipham + phenmedipham alone.

**Layby Herbicides**

SU18. Trifluralin (Treflan) at 0.75 lb/A is cleared for use on sugarbeets when the sugarbeets are 2 to 6 inches tall and well rooted. Exposed beet roots should be covered with soil before application. Emerged weeds are not controlled. Trifluralin may be applied over the tops of the sugarbeets and incorporated with a harrow, rotary hoe, or cultivator adjusted to mix the herbicide in the soil without excessive sugarbeet stand reduction. Use of trifluralin can reduce the emergence of late season weeds which often cause problems in sugarbeets. EPTC (Eptam) at 3 lb/A is cleared as a layby herbicide for sugarbeets and should be applied similarly to trifluralin. However, the greater volatility of EPTC and the greater need for thorough incorporation make EPTC less likely to be effective as a layby herbicide than trifluralin. EPTC can also be applied by metering the herbicide into irrigation water. EPTC should be applied in the first irrigation after the last cultivation of the season.

Table SU1. Summary of herbicides for use on sugarbeets.

| Herbicide | Act. ingred. lb/A (Formulation/A) | Weeds | When to Apply | Remarks | Ref.* |
|---|---|---|---|---|---|
| **Glyphosate** (Roundup) | 0.19 to 0.75 (0.5 pt to 1 qt) | Emerged annual grasses and broadleaf weeds | Preplant or any-time prior to crop emergence | A nonselective, translocated postemergence herbicide. No soil residual activity. | SU5 |
| **Paraquat** (Gramoxone) | 0.5 (1 qt) | | | A nonselective, postemergence herbicide. No soil residual activity. Apply with X-77. Good coverage is essential. Restricted use herbicide. | SU4 |
| **EPTC** (Eptam, Genep) | 2 to 3 (2.3 to 3.4 pt) | Annual grasses and some broad-leaf weeds | Preplant incorporated | Some stand reduction and temporary stunting may occur from the use of EPTC. Weak on wild mustard. | SU7, SU8 |
| | 4 to 4.5 (4.5 to 5.25 pt 7E, 40 to 45 lb 10G) | | Fall incorporated after October 15 until freeze-up | | |
| **Cycloate** (Ro-Neet) | 3 to 4 (4 to 5.3 pt 6E, 30 to 40 lb 10G) | | Preplant incorporated | Sugarbeets have better tolerance to cycloate than to EPTC. Weak on wild mustard. Weed control poor on fine-textured, high organic matter soils. | SU9 |
| | 4 (5.3 pt 6E, 40 lb 10G) | | Fall incorporated after October 15 until freeze-up | | |
| **Diallate** (Avadex) | 1.5 to 2 (1.5 to 2 qt, 15 to 20 lb 10G) | Wild oats | Spring-preplant incorporated. Fall-after October 15 and until freeze-up | Operating tillage implement 4 inches deep does not reduce wild oats control. Restricted use herbicide. | |
| **Ethofumesate** (Nortron) | 2 to 3.75 (1.5 to 2.5 gal E or 2 to 3.75 qts F) | Some annual grasses and broadleaf weeds. Especially good on redroot pigweed | Preemergence or preplant incorporated in band | Incorporation generally improves weed control. | SU7 |
| **Diethatyl** (Antor) | 4 to 6 (1 to 1.5 gal) | Redroot and prostrate pigweed and some annual grasses | Preemergence or preplant incorporated | Shallow (1 to 2 inch) incorporation gives best results. | SU13 |
| **TCA** | 4.7 to 7.1 (8 to 12 pt) | Most annual grasses | Premergence | Weak on wild oats. Do not use sugarbeet tops for livestock feed. | SU7, SU10 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

**Table SU1. Summary of herbicides for use on sugarbeets (continued)**

| Herbicide | Act. Ingred. lb/A (Formulation/A)* | Weeds | When to Apply | Remarks | Ref.* |
|---|---|---|---|---|---|
| **Pryazon** (Pyramin) | 3.1 to 7.6 (3 to 7.25 qt F) | Most broadleaf weeds | Preemergence | Has been less effective on soils with more than 5% organic matter. Incorporation improves performance of pyrazon. | SU11 |
| **Desmedipham + Phenmedipham**(Betamix) | 0.16 to 0.6 + 0.16 to 0.6 (2 to 7.5 pt) | Most annual broadleaf weeds | Postemergence when broadleaf weeds are from cotyledon to 4-leaf stage. Sugarbeets with less than 4 leaves will tolerate 0.32 to 0.5 lb/A of these herbicides and sugarbeets with 4 leaves or more will tolerate higher rates. | Risk of sugarbeet injury is reduced by starting application in late afternoon and risk is increased by certain environments. (See paragraph 119). Split application with reduced rates has reduced sugarbeet injury and increased weed control compared to single full dose application. | SU14, SU17 |
| **Desmedipham** (Betanex) | 0.23 to 1.2 (2 to 7.5 pt) | | | | |
| **Endothall** (Herbicide 273) | 0.75 to 1.5 (2 to 4 pt) | Wild buckwheat, smartweed, volunteer sunflower | Sugarbeets should have 4 to 6 leaves. Do not apply later than 40 days after emergence. | When temperatures are over 80 F, endothall may cause excessive injury, especially to very small sugarbeets. Endothall is ineffective at temperatures below 60 F or when weeds are drougth stressed. | SU15 |
| **Ethofumesate** (Nortron EC)+ **Desmedipham** (Betanex) | 1.12 to 1.5 + 0.73 to 1 (0.75 to 1 gal E + 4.5 to 6.1 pt) | Most annual broadleaf weeds | Postemergence when sugarbeets have at least 6 leaves. Half rate may be applied to 4-leaf sugarbeets. | Improved weed control and increased risk of sugarbeet injury compared to desmedipham or desmedipham + phenmedipham. Split applicaton at half rates has reduced sugarbeet injury and increased weed control compared to single full dose application. | SU12, SU17 |
| **Ethofumesate** (Nortron EC) + **Desmedipham** + **Phenmedipham** (Betamix) | 1.12 to 1.5 + 0.365 to 0.5 + 0.365 to 0.5 (0.75 to 1 gal E + 4.5 to 6.1 pt) | | | | |
| **Sethoxydim** (Poast) | 0.1 to 0.5 (0.5 to 2.5 pt) | Wild oats, foxtail, (pigeongrass) volunteer grain, wild | Wild oats 1 to 4 inches, foxtail (pigeongrass) 3 to 8 inches, volunteer wheat or barley 1 to 6 inches wild proso millet 4 to 10 inches. | Apply to actively growing grasses. See narrative for rates for different grass species. Always apply with oil concentrate at 1 qt/A. | SU16 |
| **Trifluralin** (Treflan) | 0.75 (1.5 pt 4E) | Grass and some broadleaf weeds | Sugarbeets 2 to 6 inches tall and well-rooted to withstand incorporation. | Must be incorporated. Exposed beet roots must be covered with soil before application. May be applied over the tops of sugarbeets. | SU18 |

*Reference paragraph number indicates appropriate paragraph in the narrative.

Table SU2. Effectiveness of herbicides on major weeds in sugarbeets.

| Herbicides | Eastern black nightshade | Barnyardgrass | Cocklebur | Field bindweed & P. thistle | Foxtails (pigeongrass) | Kochia | Common lambsquarters | Pigweed, redroot | Russian thistle | Sunflower, volunteer | Wild buckwheat | Wild mustard | Wild oats | Herbicide persistence after 12 months |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Preemergence or Preplant Incorporated** | | | | | | | | | | | | | | |
| Antor (diethatyl) | F-G | F-G | P | P | F-G | P | P | G | P | P | P | P | F-G | N |
| Avadex (diallate) | N | N | N | N | N-F | N | P-F | N | N | N | N | N | G | N |
| Eptam (EPTC) | F-G | G | P | N | G | F | F | F-G | P | N | F | P | F-G | N |
| Nortron (ethofumesate) | F-G | P | P | N | F-G | F-G | P-F | G | F-G | P | F-G | F | F-G | O |
| Pyramin (pyrazon) | G | P | P-F | P | P | P-F | G | G | P-F | P | P-F | G | P | N |
| Ro-Neet (cycloate) | F-G | G | P | N | G | P | F-G | F-G | P | N | F-P | P | F-G | N |
| TCA | N | G | N | N | G | N | N | N | N | P | N | N | N | N |
| **Postemergence** | | | | | | | | | | | | | | |
| Betamix (desmedipham + phenmedipham) | G | P | F | N | F | F | G | F-G | P | P | F-G | G | N | N |
| Betanex (desmedipham) | G | P | P-F | N | P | P-F | G | G | P | P | F | G | N | N |
| Herbicide 273 (endothall) | - | N | P-F | N | N | P | P | P-F | P | F-G | G | F | N | N |
| Nortron (ethofumesate) + Betamix | G | F | F-G | N | F-G | F-G | G | G | P-F | P | G | G | P | N |
| Nortron (ethofumesate) + Betanex | G | F | F | N | F | F | G | G | P-F | P | F-G | G | P | N |
| Poast (sethoxydim) | N | G | N | N | G | N | N | N | N | N | N | N | G | N |
| Layby Treflan (trifluralin) | N | G | N | N | G | G | G | G | N | N | F | N | F | N |

G = Good, F = Fair, P = Poor, N = None, O = Often, - = No data

## SUNFLOWERS

SF1. Weed identification should be the first step in effective weed control. After weeds are identified, select the best herbicide for control. If sunflower fields have several weed species or hard-to-control weeds, a combination of two herbicides is often more effective than one. Be sure to compare herbicide prices. Make sure you are getting the best weed control possible at the best price. Herbicide costs can be reduced by applying herbicides in a band over the sunflower row. However, timely cultivation is then needed to control weeds between the rows. Accurate calibration of your spray equipment can also help reduce herbicide costs. Under-application of an herbicide is costly due to ineffective weed control. Applying more herbicide than necessary adds to your herbicide costs, and may also result in sunflower injury.

### Cultural Practices

SF2. Harrowing and cultivation are important methods of weed control in sunflowers. Since sunflowers normally do not emerge for ten days to two weeks after planting, shallow tillage with a spike tooth or coil spring harrow can be used about one week after planting to kill many weeds. Because sunflower seedlings are strongly rooted, these implements and others such as the weeder and rotary hoe can also be used to kill weeds after the sunflowers emerge. However, the tillage implements must be properly adjusted, and tillage after sunflower emergence should be delayed until the sunflower seedlings have two or more leaves. Harrowing may normally be done several times if weeds continue to emerge and if field conditions are suitable. Weeds missed by early tillage may be controlled by cultivation between the rows. However, for adequate weed control, tillage will probably need to be supplemented by chemical control.

### Herbicides

SF3. Proper herbicide application and favorable soil and weather conditions are necessary for optimum herbicide performance. The soil should be dry enough to be easily worked, not wet or cloddy, to ensure maximum mixing of the herbicide with the soil during preplant herbicide incorporation. Adequate soil moisture is needed to ensure good herbicide activity. Dry conditions at the point where the germinating weed seedlings contact the herbicide will reduce effectiveness.

SF4. Alachlor (Lasso) can be applied preemergence or preplant incorporated. Alachlor controls annual grasses, nutsedge, redroot pigweed and nightshade. Wild oat control is not adequate. Control of other broadleaf weeds has been erratic. Preplant incorporated applications have generally given more consistent control. Alachlor will probably be a Restricted Use Herbicide in 1988.

SF5. Barban (Carbyne 2EC) can be applied early postemergence for wild oat control. Apply when the majority of wild oats are in the 2-leaf stage. Apply in 5 to 10 gallons of water/A using sufficient pressure (min. 45 psi) to break spray into small droplets.

SF6. Chloramben (Amiben) can be applied preemergence or preplant incorporated. Chloramben can also be applied as an overlay treatment when EPTC (Eptam/Genep), alachlor (Lasso), pendimethalin (Prowl) or trifluralin (Treflan) are applied preplant incorporated. Chloramben controls annual grasses (except wild oats) and many annual broadleaf weeds. Wild mustard control has been inconsistent. With preemergence applications, a minimum of 0.5 inches of rainfall within ten days of application is needed for effective weed control. If a preemergence application of chloramben is followed by dry weather and weed seedlings start to emerge, an early shallow cultivation will be necessary.

SF7. EPTC (Eptam/Genep) can be applied preplant incorporated in the fall or spring for annual grass control. Wild oat control is generally not adequate. EPTC is volatile, therefore, it should be incorporated immediately after application to prevent herbicide loss. Rate is dependent on soil type.

SF8. Ethalfuralin (Sonalan) can be applied preplant incorporated for control of annual grasses and common lambsquarters, kochia and pigweed. Wild oat control is not adequate. Ethalfuralin has not given satisfactory wild mustard control. Rate is dependent on soil type.

SF9. Paraquat (Gramoxone Super) may be applied preplant or anytime prior to sunflower emergence to control emerged annual grasses and broadleaf weeds. Paraquat has no soil residual. Apply with Ortho X-77. Paraquat may also be used as a sunflower dessicant on oilseed varieties only. Do not apply until sunflowers have reached physiological maturity (35 percent moisture). Paraquat is a restricted use herbicide because it is highly toxic to humans.

SF10. Trifluralin (Treflan) and pendimethalin (Prowl) may be applied preplant incorporated in the fall or spring to control annual grasses and some broadleaf weeds. Wild mustard and wild oat control is not satisfactory. Rate is dependent on soil type. Trifluralin can be tank mixed with chloramben (Amiben) or EPTC (Eptam/Genep). Pendimethalin (Prowl) may be tank mixed with chloramben (Amiben).

SF11. Ethalfluralin (Sonalan), pendimethalin (Prowl), and trifluralin (Treflan) are all chemically related herbicides called dinitroanilines. Under cold or dry soil conditions these herbicides may persist for more than one year. Sensitive crops such as small grains, grain sorghum, or sugarbeets can be affected the following year. Moldboard plowing reduces the potential of crop injury from residues of these herbicides.

Table SF1. Summary of herbicides for use on sunflowers.

| Herbicide | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **Preemergence, Preplant or Preplant Incorporated** | | | |
| **alachlor** (Lasso) | 3 (3 qt, 20 lb 15G) | Apply preemergence or preplant incorporated for annual grass control and some broadleaf weed control. Preplant incorporated has given more consistent control. No wild mustard control. | SF4 |
| **chloramben** (Amiben) | 2 to 3 (several formulations) | Apply preemergence or preplant incorporated to control annual grassy weeds and many broadleaf weeds. At least 0.5 inch of rain is necessary within 10 days of application for effective weed control when applied preemergence. Inconsistent wild mustard control. Rate is dependent on soil type. | SF6 |
| Labeled mixtures | | | |
| alachlor (Lasso) | .75 to 1.5 | Apply preplant incorporated. Rate dependent on soil type. | |
| EPTC (Eptam/Genep) | 2.2 to 3.1 | Apply preplant incorporated. Rate dependent on soil type. | |
| pendimethalin (Prowl) | .75 to 1.25 | Apply preemergence or preplant incorporated. Use lower rate on soils with less than 3% organic matter. | |
| trifluralin (Treflan) | .5 to 1 | Apply preplant incorporated. Use low rate on coarse-textured soils. | |
| **EPTC** (Eptam/Genep) | 2 to 3 (2.3 to 3.4 pt) | Apply preplant incorporated in spring to control annual grassy weeds and some broadleaf weeds. No wild mustard control. Rate is dependent on soil type. | |
| | 4 to 4.5 | Apply fall incorporated after October 15 until soil freeze-up. No wild mustard control. Controls annual grassy weeds and some broadleaf weeds. Rate is dependent on soil type. | |
| **ethalfluralin** (Sonalan) | 0.57 to 1.12 (1.5 to 3 pts/A) | Apply preplant incorporated for the control of annual grassy weeds and some broadleaf weeds. Weak on wild mustard. See narrative for recropping restrictions. Rate is dependent on soil type. | SF8, SF11 |
| Labeled mixtures | | | |
| chloramben (Amiben) | 2 to 3 | Apply as a preplant incorporated tank mix or as an overlay to a preplant incorporated ethalfuralin application. Rate is dependent on soil type. | |
| EPTC (Eptam/Genep) | 2.2 + 3.1 | Apply preplant incorporated. Rate is dependent on soil type. | |
| **paraquat** (Gramoxone Super) | 0.5 (1.34 qts) | Apply preplant or anytime prior to sunflower emergence. Controls emerged annual grassy and broadleaf weeds. Apply with Ortho X-77. | SF9 |
| **fluchloralin** (Basalin) | 0.5 to 1.5 (1 to 3 pts) | Apply preplant incorporated. Controls annual grasses and some broadleaf weeds. No wild mustard control. | |

**Table SF1. Summary of herbicides for use on sunflowers (continued).**

| Herbicide | Active ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **pendimethalin** (Prowl) | 1 to 1.5 (2 to 3 pts) | Apply preplant incorporated in the fall or spring to control annual grasses and some broadleaf weeds. Rate dependent on soil type. | SF10, SF11 |
| Labeled mixtures | | | |
| chloramben (Amiben) | 2 | Apply preplant incorporated in the spring as a tank mix with pendimethalin or as a overlay application to a preplant incorporated application of pendimethalin. | |
| **trifluralin** (Treflan) | 0.5 to 1 (1 to 2 pts) | Apply preplant incorporated to control annual grassy weeds and some broadleaf weeds. Weak on wild mustard. | SF10, SF11 |
| | 0.5 to 1 (5 to 10 lb TR-10) | Apply preplant incorporated in the fall after September 1. Weak on wild mustard. | |
| Labeled mixtures | | | |
| chloramben (Amiben) | 2 to 3 | Apply preplant incorporated in the spring as a tank mix with trifluralin or as an overlay application to a preplant incorporated application of trifluralin. Rate dependent on soil type. | |
| **EPTC** (Eptam/Genep) | 3 to 4.6 (3.5 to 5.25) | Apply preplant incorporated in fall or spring. Incorporate immediately after application. | SF7 |
| **Postemergence** | | | |
| **barban** (Carbyne 2EC) | 0.375 (1.5 pts) | Apply when the majority of wild oats are in the 2-leaf stage, but within 30 days after sunflower emergence. | SF5 |
| **Desiccants** | | | |
| **paraquat** (Gramoxone Super) | .25 to .5 (.67 to 1.34) | Use on oilseeds only. Apply with Ortho X-77. Apply when sunflowers have reached physiological maturity. **Restricted use herbicide.** | SF9 |

*Reference number indicates appropriate paragraph in the narrative.

Table SF2. Effectiveness of herbicides on major weeds in sunflower

| Herbicides | Type of application | Sunflower tolerance | Grasses: Giant foxtail | Grasses: Green & yellow foxtail | Grasses: Wild oats | Broadleafs: Cocklebur | Broadleafs: Common lambsquarters | Broadleafs: Common ragweed | Broadleafs: Kochia | Broadleafs: Pigweed spp. | Broadleafs: Smartweed spp. | Broadleafs: Wild mustard |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| alachlor (Lasso) . . . . . . . . . | PRE/ PPI | G | G | G | P | P | F | P | P | G | P | P |
| barban (Carbyne 2EC) . . . . . . | POST | G | N | N | G | N | N | N | N | N | N | N |
| chloramben (Amiben). . . . . . . | PRE/ PPI | G | G | G | P | P | G | G | G | G | G | F |
| EPTC (Eptam/Genep) . . . . . . . | PPI | G | G | G | F | P | F | F | F | F | P | P |
| ethalfluralin (Sonalan). . . . . | PPI | G | G | G | F | N | G | N | G | G | P | N |
| fluchloralin (Basalin) . . . . . | PPI | G | G | G | P | N | G | N | G | G | P | N |
| pendimethalin (Prowl). . . . . . | PPI | G | G | G | P | N | G | P | G | G | F | P |
| trifluralin (Treflan). . . . . . | PPI | G | G | G | P | N | G | N | G | G | P | N |

G = Good, F = Fair, P = Poor, N = No control, Pre = Preemergence, PPI = preplant, PPI = preplant incorporated, POST = Postemergence

## PERENNIAL WEED PROBLEMS

P1. Perennial weeds are usually more difficult to control than annuals because they persist and spread by vegetative means as well as seeds. Stems, roots and tubers store food and produce new shoots whenever the top growth is killed by control practices or freezing temperatures. The spreading growth of a perennial's roots or stems enlarge weed patches and tillage implements start new infestations by transporting and transplanting reproductive plant parts throughout the field. As with annual weeds, seeds produced each year can be spread by wind, rain, animals or man, and initiate new infestations. Perennial weeds should never be allowed to produce seeds.

The elimination of perennial weeds requires the killing of all plant parts that are capable of producing new shoots. If the plant parts are near the soil surface, tillage can be used to bring them to the soil surface to dry out and die. However, these plant parts are frequently located too deep in the soil to be reached with tillage. Some herbicides, such as 2,4-D or glyphosate, can move downward in the plant, causing injury or killing some of the plant parts below the plow layer. However, the underground reproductive parts of perennial weeds are most frequently killed by starvation. To accomplish this, shoots produced at the expense of underground food reserves must be destroyed before they become large enough to replenish the depleted underground reserve. This process must be done repeatedly.

Most perennial weed infestations can be controlled in crops by the judicious integration of tillage, cultivation, crop selection, crop management and herbicide usage. Careful timing of tillage, planting, cultivation, fertilization and herbicide application is required to inflict the maximum injury to the weed with the least effect on the crop. The reduction or elimination of perennial weed infestations requires more than the prevention of seed production in crops. In addition, the control of shoot growth must be continued throughout the year. The prevention of vigorous shoot growth in the fall after crop harvest is especially important in blocking the replenishment of underground food reserves. If permitted, the replenishment of underground food reserves will result in continued vigor of the weed infestation the next year. Usually, repeated suppression of perennial weed growth by tillage, cultivation or herbicide treatment for two or more years is required for eradication of perennial weed infestations.

### Characteristics of Troublesome Perennial Weeds

P2. <u>Canada thistle</u>. Canada thistle, a Minnesota "Primary Noxious Weed," is the most prevalent broadleaf perennial weed in the state. It is found in all crops and pastures and develops into highly competitive dense patches of shoots arising from spreading horizontal roots. Spiny, crinkled leaves with shoots up to 4 feet tall produce colorful lavender flowers on separate male and female plants. Mature seeds, suspended on a feathery pappus, become windborne and can be transported tens to hundreds of miles by the wind. Canada thistle shoots should be destroyed before mature seeds are produced. The deep root system stores food reserves and produces new shoots. Control depends on destruction of the root system or depletion of the food reserves. Destruction of the root system with single herbicide treatments or tillage operations is seldom achieved. However, depletion of food reserves by using repeated tillage or herbicide applications to prevent the development of vigorous shoots can be accomplished without sacrificing crop production. Programs that eliminate vigorous Canada thistle shoot growth for two years, both in the crops and in the fall after crops have been harvested, usually result in Canada thistle elimination. Elimination of this weed should be the goal of every farmer in Minnesota.

P3. Common milkweed. Common milkweed is a perennial native to Minnesota that is on the increase because of its tolerance to most herbicides combined with the poorer suppresssion of this weed obtained by the reduced tillage systems now in use, than was attained by the more intensive conventional tillage used in the past. Milkweed infestations are common in both cropland and non-cropland throughout Minnesota. Common milkweed has a stout stem, 2 to 5 feet tall with large, 4 to 8 inch, oblong opposite leaves with large, round clusters of sweet-smelling flowers with a milky juice. The seeds, each with a tuft of silky hairs, are produced in a large pod. Common milkweed spreads by windborne seeds, creeping roots that can grow 10 feet radially per year, and root segments which are transported and transplanted by tillage implements. Frequent tillage and competitive crops, such as alfalfa and winter wheat, greatly reduce the vigor of milkweed. Herbicides are relatively ineffective on this weed so suppression in crops with herbicides is poor. Wiper applications of glyphosate (Roundup) to milkweed that is 6 or more inches taller than the crop suppresses shoot growth. High rates of 2,4-D ester or picloram (Tordon) in grass pastures or non-crop areas will suppress milkweed. For elimination, repeated shoot destruction by tillage or herbicides over several years is required.

P4. Field bindweed. Field bindweed, also called "creeping jenny" or "morningglory", a Minnesota Primary Noxious Weed, is found throughout the state, but the heaviest infestations are in the western half. It spreads by seeds and rootstocks that are transported and transplanted by tillage implements. Shoots are vines up to 7 feet long with arrow-shaped leaves and large white or pink funnel-shaped flowers. The roots penetrate the soil to a depth of 20 to 30 feet and store vast quantities of food which must be depleted by tillage or with herbicides to eliminate this weed. Vigorous shoot growth must be prevented throughout the growing season using a combination of competitive crops, such as alfalfa, herbicide treatments in the crop and after harvest, and tillage or cultivation. Dicamba (Banvel), and 2,4-D provide shoot suppression in small grains and corn and can be supplemented with a glyphosate (Roundup) spot treatment or broadcast sprays before or after crops ar grown. Picloram (Tordon) use is limited to spot treatment in grass pastures.

P5. Leafy spurge. Leafy spurge, a Minnesota "Primary Noxious Weed," is present throughout the state with the heaviest infestations along the western border. It is more prevalent in permanent pastures and non-crop areas, and is occasionally a problem in cropland. New shoots arising from root buds, begin growth early in the spring, which gives this weed a competitive advantage over crops. Strap-like narrow leaves arise from a smooth upright stem, 1 to 2 feet tall, contain a milky juice, and are topped by a cluster of small greenish flowers each of which is enclosed in showy greenish-yellow floral bracts. Spread of an infestation is by creeping roots, seeds and the transport and transplanting of root segments by tillage implements. Control depends on depletion of food reserves in the extensive, deep, 8 feet or more, root system by preventing vigorous shoot growth throughout the growing season with tillage or herbicides. Dicamba and 2,4-D used repeatedly alone or in mixtures give only partial suppression of leafy spurge. In grass pastures, picloram (Tordon) at high rates provides better control than 2,4-D or dicamba, but is very costly. Repeated applications of picloram- 2,4-D mixtures are effective and less expensive. Fall applications of glyphosate (Roundup) provide good control, but follow-up treatments with 2,4-D are required to control new seedlings.

P6. Perennial sowthistle. Perennial sowthistle, a Minnesota Primary Noxious Weed, is found throughout the state with the heaviest infestations in the west and north. It spreads by windborne seed and from buds on underground roots which produce dense patches of this weed and are transplanted to new areas by tillage implements. Shoots are large, 3 to 7 feet tall, with showy yellow flowers, large leaves edged with soft spines and containing a milky juice. Much of the root system extends several feet below the plow layer so it cannot be reached by tillage. Reducing infestations requires the prevention of vigorous shoot growth over two or more years; using herbicides in crops and herbicides or tillage when a crop is not present. Effective treatments in crops include dicamba (Banvel), 2,4-D or MCPA as listed on their labels plus glyphosate (Roundup) in spot treatments or as wiper applications. All of these herbicides can be used on non-cropland.

P7. Quackgrass. Quackgrass, present in both cropland and pastures, is the most prevalent perennial grass weed in Minnesota. Shallow underground stems, called rhizomes, give rise to new shoots and are the major means of survival and spread of this weed. Tillage may increase or decrease quackgrass infestations. Tillage implements can drag rhizome segments to the soil surface where they dry out and die, or can drag the rhizomes to uninfested areas where they take root and start new infestations. Atrazine and Roundup, when properly used, provide excellent quackgrass control. The widespread use of these herbicides could result in the elimination of quackgrass as a major weed in Minnesota. In soybeans, suppression but not elimination of quackgrass can be achieved with fluazifop (Fusilade) or sethoxydim (Poast).

P8. Wirestem mulhy. Wirestem muhly is a perennial grass found on limited acreages in southern Minnesota. It spreads by seeds and short rhizomes. Growth starts later in the spring than quackgrass with the smooth, very tough leafy stems reaching a height of 2 to 3 feet. Growth from the rhizomes forms a dense sod. Since the roots and rhizomes are very shallow, tillage can be used to bring these parts to the soil surface where they dry out and die. However, tillage implements spread the infestation by carrying plant parts to other parts of the field. Since growth starts later in the spring, small grains planted early greatly suppress the growth of wirestem muhly. Atrazine in corn, sethoxydim (Poast) and fluazifop (Fusilade) in soybeans, and glyphosate (Roundup) in non-crop areas are herbicides to use in controlling this weed.

P9. Yellow nutsedge. Yellow nutsedge is a perennial weed that propagates from seeds and from underground tubers (nuts) which are formed on short rhizomes. It is on the increase in Minnesota. The grass-like leaves of nutsedge are light green and the seedheads are yellow to brown. The nuts are 1/8 to 1/2 inch in diameter and tan to brown in color. The stems are triangular in cross section. Nutsedge usually becomes established in wet areas of fields. The weed is spread by tillage operations which scatter the seeds and tubers into unifested areas.

Nutsedge can be controlled, but usually not eliminated, by using a combination of cultural practices and chemicals. Infested areas in fields should be tilled separately from the remainder of the field to avoid transporting plant parts to clean areas of the field. Nutsedge is not tolerant to shading so growing crops with a dense canopy such as narrow-rowed soybeans helps suppress nutsedge. Repeated cultivations are usually needed to destroy regrowth and new seedlings, even when chemicals are used.

Fallowing has given effective control of yellow nutsedge in dry years, but, in wet years, the tubers are just transplanted and continue to grow. Disking or dragging about every 3 weeks or when sprouts appear should considerably reduce the nutsedge population in a dry year.

Preplanting incorporated application of high rates of alachlor (Lasso), metolachlor (Dual), or EPTC with protectant (Eradicane) in corn and alachlor, metolachlor or vernolate (Vernam) in soybeans usually gives good nutsedge control. If other crops that are tolerant to EPTC such as potatoes, sunflowers, or dry edible beans can be grown in the infested areas, EPTC without the protectant may be used to control nutsedge.

Some regrowth and new plants can be expected to occur following herbicide applications. These can be controlled by cultivation. In corn, early postemergence applications of atrazine and oil have been effective in controlling regrowth following preplanting treatments with the chemicals discussed above.

Bentazon (Basagran) may be used as a postemergence treatment to control nutsedge in corn, dry beans and soybeans. Two applications of 3/4 to 1 pound per acre each have been more effective than a single application of 1 to 1-1/2 pounds per acre. Apply the first application when the nutsedge is 6 to 8 inches tall. Repeat the treatment 7 to 10 days later. If a single application is used, apply when the tallest nutsedge is 6 to 8 inches. Addition of a non-phytotoxic oil concentrate increases the activity of bentazon.

**Characteristics of Some Herbicides Frequently Used For Perennial Weeds**

P10. Atrazine (AAtrex). Atrazine is active on Canada thistle, yellow nutsedge and, especially quackgrass, in both soil and foliar applications applied to corn. Postemergence foliar burndown with atrazine plus crop oil is supplemented by the atrazine residual in the soil which suppresses regrowth. Regrowth suppression can be improved and extended by splitting the atrazine application; thereby improving the degree of control. For quackgrass control in corn, apply part of the atrazine in the fall and the remainder in the spring. The higher atrazine application rates required for perennials increases the potential for atrazine carryover, so only corn can be planted the following year.

P11. Bentazon (Basagran). Postemergence bentazon treatments provide effective control of Canada thistle and yellow nutsedge in corn and soybeans. It is not effective on other perennial weeds. Crop tolerance is good and there are no problems of spray drift or carryover when bentazon is used. Bentazon controls shoot growth of these weeds, but does not eradicate the underground reproductive organs so retreatments are necessary.

P12. Chlorsulfuron (Glean). Postemergence chlorsulfuron applications to small grains suppress Canada thistle shoots and prevents seed production. Chlorsulfuron is not effective on other perennial weeds. Do not use on land where the soil pH exceeds 7.5 or if rotational crops other than small grains will be grown the following year.

P13. Dicamba (Banvel). Dicamba, used postemergence, provides excellent shoot suppression of perennial broadleaf weeds in corn and small grains. Higher postemergence rates, used in grass pastures, non-crop areas or in cropland when a crop is not present, can severely reduce but seldom eliminate broadleaf perennial infestations. Two dicamba treatments per year for several years will eliminate many of the perennial broadleaf weeds that are more sensitive to dicamba, such as Canada thistle, perennial sowthistle, and field bindweed. Leafy spurge and common milkweed are more difficult to control with dicamba. Time the treatments to prevent the development of large vigorous shoots, capable of replenishing underground food reserves. Carryover injury to sensitive crops such as soybeans, sunflowers, or sugarbeets is a possibility when high rates are applied in the late fall with the carryover potential being greatest in northwestern Minnesota.

P14. Fluazifop (Fusilade) and Sethoxydim (Poast). Postemergence fluazifop and sethoxydim give suppression of quackgrass and wirestem muhly in soybeans. They are not effective on other perennial weeds. Soybean tolerance is very good and soil residuals are not a problem with rotational crops. These herbicides provide suppression rather than eradication of quackgrass and wirestem muhly.

P15. Glyphosate (Roundup). Glyphosate is a non-selective herbicide that, when applied postemergence, is very effective on many broadleaf and grassy perennial weeds, especially quackgrass. However, it is not active through the soil. It will kill all emerged crops or weeds, but has no residual effects on plants that emerge after the glyphosate application. For the best results, apply to vigorous, well developed, shoot growth of perennial weeds. Research results indicate that applications of glyphosate to foliage wet with dew or rain are reduced in effectiveness. Late fall applications are effective if the weed foliage has not been injured by frost. Treating perennial weed regrowth after tillage is less effective than treating before tillage.

P16. MCPA. Postemergence treatments with MCPA are toxic on many broadleaf perennial weeds. However, 2,4-D is considered to be slightly more effective than is MCPA on most of them, except the perennial buttercups, which are more susceptible to MCPA than to 2,4-D.

P17. Picloram (Tordon). Picloram is one of the most effective herbicides for the control of perennial broadleaf weeds because of its long persistence in the soil. Postemergence applications kill emerged shoots and picloram residues will remain active in the soil and inhibit or kill regrowth, often for more than one growing season in Minnesota. While long persistence gives more effective control of perennial broadleaf weeds, it also limits use of picloram to grass pastures and non-crop areas. Picloram is classified as a "Restricted Use Pesticide" because of its long persistence and leachability. Careful site selection is required to avoid surface and ground water contamination. Most broadleaf crops are very sensitive to picloram, so avoid drift onto nearby broadleaf plants.

P18. 2,4-D. Postemergence application of 2,4-D has been the major herbicide practice on broadleaved perennials since the early 1950's. It provides excellent top growth control of many broadleaf perennials, but does not provide adequate kill or regrowth suppression of underground buds due to its short persistence of only a few weeks, in the soil. Some 2,4-D tolerant weeds such as common milkweed, leafy spurge and germander are on the increase in Minnesota and more effective alternative herbicides should be used on these species. Lower rates of 2,4-D will suppress shoot growth and prevent seed production of many perennial broadleafs in corn and small grains. Higher rates of 2,4-D after crop harvest can be used to prevent vigorous fall regrowth. Higher rates of 2,4-D used in grass pastures and non-crop areas stop seed production and the vegetative spread of susceptible broadleaf perennials throughout the summer, but fall treatments should be used if regrowth occurs.

Table P1. Herbicide choices for perennial weeds in cropland pastures.

| Weed and Herbicides | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **CANADA THISTLE AND PERENNIAL SOWTHISTLE** | | | P2, P6 |
| **atrazine** | 4 | For corn only. Preemergence or postemergence or split preemergence plus postemergence. Use oil additive postemergence. Corn only must be planted the following year to avoid carryover injury to other crops. | P10 |
| (AAtrex or Atrazine 80W) | (5 lb) | | |
| (AAtrex or Atrazine 4L) | (4 qt) | | |
| (AAtrex Nine-O) | (4.4 lb) | | |
| | 10 to 20 | Non-crop areas. Kills all vegetation. | |
| **bentazon** | 1 | For soybeans and corn. Postemergence on thistle shoots from 8 inches to bud stage. Repeat in 7 to 10 days if necessary. | P11 |
| (Basagran) | (2 pts) | | |
| **chlorsulfuron** | .016 to .023 | For wheat, barley and spring oats. Postemergence for suppression of thistle shoots. Important: See label restrictions on rotational crops and recropping. | P12 |
| (Glean) | (1/3 to 1/2 oz) | | |
| **dicamba** | .12 to 5 | For corn and small grains. Postemergence for thistle suppression. See specific crops for use rates and timing. Avoid spray or vapor drift onto soybeans or other sensitive crops. | P13 |
| (Banvel) | (1/2 to 1 pt) | | |
| | 2 to 4 | For grass pastures, non-crop areas or post-harvest. Postemergence when thistles over 8 inches tall. Important: See label for pasture grazing and rotational crop restrictions. | |
| **glyphosate** | 1.5 to 2.25 | For non-cropland, spot treatment of thistle patches, or on cropland before crop emergence or after crop harvest. Apply postemergence as a spray or with wiper applicators to thistles at or beyond the bud stage. Crops contacted by spray or drift will be injured or killed. Apply fall treatments before killing frosts. | P15 |
| (Roundup) | (2 to 3 qt) | | |
| **MCPA** | .38 to 1.5 | For small grains, flax and pasture. Postemergence for thistle suppression. See label for rates and spray timing on specific crops. Flax is more sensitive than small grains. | P16 |
| amines | (.75 to 3 pts) | | |
| esters | (1.3 to 3 pts) | | |
| **picloram** | .5 to 1 | For grass pastures and non-crop areas spot treatment or broadcast when thistles are growing well. Use lower rate in broadcast treatments. | P17 |
| (Tordon) | (1 to 2 qts) | | |
| **2,4-D** | .5 to 2 | For corn, small grains and pastures. Postemergence 12 inches tall to bud stage. See label for rates and spray timing on specific crops. Higher rates in pastures and after harvest in the fall. | P18 |
| amines | (.5 to 2 qt) | | |
| esters | (.5 to 2 qt) | | |

Table P1. Continued.

| Weed and Herbicides | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **COMMON MILKWEED** | | | P3 |
| **glyphosate** (Roundup) | 2.25 (3 qts) | For pasture and non-cropland. Spot treatment at late bud to flower stage. Wiper application of 33% solution in crop to milkweed more than 6 inches taller than crop. | P15 |
| **picloram** (Tordon) | .5 to 2 (1 to 4 qts) | For spot treatment or pastures. Use high rates for spot treatments and low rate for broadcast pasture application. | P17 |
| **2,4-D, ester + dicamba** (Banvel) | 1 + .25 (2 + .5 pt) | For pasture and non-cropland. Postemergence at bud to bloom. Growth suppression only. Avoid spray drift onto sensitive plants. | P18 |
| **FIELD BINDWEED** | | | P4 |
| **dicamba** (Banvel) | .13 to .5 (.25 to 1 pt) | For small grains and corn. Postemergence for suppression in crop. See label for specific rates and timing. Avoid spray and vapor drift onto soybeans and other nearby sensitive plants. Can replace part of dicamba with 2,4-D to reduce cost. | P13 |
| **glyphosate** (Roundup) | .5 to 8 (.5 to 4 qts) | For pasture, non-cropland or post-harvest. Postemergence on new bindweed shoots in fall or bud stage in spring. Follow label restrictions on grazing after treatment. For spot treatment in crops, pastures and non-croplands or to cropland before crop emergence or after harvest. Apply postemergence sprays to vigorous shoots in the fall or at the bud stage in the spring. | P15 |
| **picloram** (Tordon) | .5 to 2 (1 to 4 qts) | For spot treatment in grass pastures and non-cropland. Postemergence when shoots are actively growing. | P17 |
| **2,4-D** (amines) (esters-LV) | .66 to .75 (.75 qt) (.66 qt) | For wheat and barley. Postemergence suppression of bindweed in the crop. | P18 |
| (amines) (esters-LV) | 1 to 3 (2 to 3 qts) (1 qt) | For grass pastures, fence rows and post harvest. Postemergence when bindweed shoots are actively growing. Repeat treatments for several years. Tank mixtures with dicamba or picloram may be used if label restrictions are observed. | |
| **LEAFY SPURGE** | | | P5 |
| **dicamba** (Banvel) | 4 to 8 (4 to 8 qts) | For grass pastures, cropland after harvest, and non-cropland. Postemergence at flowering stage or on actively growing shoots in September gives suppression. Retreatments needed. | P13 |

Table P1. Continued.

| Weed and Herbicides | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **glyphosate**<br>(Roundup) | .75<br>(1 qt) | For spot treatment in grass pastures and non-cropland. Postemergence to actively growing shoots in late summer or early fall. Will not give residual control. | P15 |
| **picloram**<br>(Tordon 22K)<br>(Tordon 2K) | 1 to 2<br>(2 to 4 qts)<br>50 to 100 lb | For spot treatment in grass pastures and non-cropland. Postemergence sprays or pellet applications to actively growing spurge. Use lower rates in tank mix with 2,4-D. Retreatments required. | P17 |
| **2,4-D**<br>(esters-LV) | 2 to 3<br>(2 to 3 qts) | For grass pastures and non-cropland. Postemergence sprays at bud to flower stage. Apply in the spring and again in the fall if actively growing shoots are present. | P18 |
| **QUACKGRASS AND WIRESTEM MUHLY** | | | P7, P8 |
| **atrazine**<br>(AAtrex or Atrazine-80W)<br>(AAtrex or Atrazine-4L)<br>(AAtrex Nine-0) | 2 to 4<br>(5 lbs)<br>(4 qts)<br>(4.4 lb) | For quackgrass and wirestem muhly control in corn. Fall and spring split application preferred. Grow corn only the year after treatment. Most effective treatment for use in corn. | P10 |
| **EPTC + safener**<br>(Eradicane) | 6<br>(7.3 pts) | For quackgrass suppression in corn. Preplant incorporated gives control of light to moderate infestation. | |
| **fluazifop**<br>(Fusilade 2000) | .19<br>(1.5 pts) | For quackgrass and wirestem control in soybeans. Postemergence to shoots 6 to 10 inches tall. Use crop oil additive. Repeat treatment if regrowth occurs. | P14 |
| **glyphosate**<br>(Roundup) | .75 to 1.5<br>(1 to 2 qts) | For quackgrass and wirestem muhly control in cropland before planting or after harvest. Postemergence to shoots 8 or more inches tall. The most effective quack-grass herbicide. No soil residual. Do not use in crops. | P15 |
| **pronamide**<br>(Kerb 50-W) | 1 to 1.5<br>(2 to 3 lbs) | For quackgrass suppression in forage legumes. Fall applications after the last cutting. Observe grazing and harvest interval restrictions. | |
| **sethoxydim**<br>(Poast) | .5 | For quackgrass and wirestem muhly suppression in soybeans and sugarbeets. Postemergence to shoots 6 inches tall. If regrowth occurs, retreat. | P14 |
| **YELLOW NUTSEDGE** | | | P9 |
| **alachlor**<br>(Lasso)<br>(Lasso II) | 3 to 4<br>(3 to 4 qts)<br>(16 to 26 lbs) | For use in corn or soybeans. Preplant incorporation required to suppress nutsedge. | |

Table P1. Continued.

| Weed and Herbicides | Active Ingredient, lb/A or (formulation/A) | Remarks | Reference* |
|---|---|---|---|
| **atrazine + oil** | 2 + 1 qt | For use in corn. Postemergence when nutsedge is 2 to 3 inches tall. Repeat if new shoots emerge or regrowth occurs. | P10 |
| (AAtrex or Atrazine 80W) | (2.5 lbs) | | |
| (AAtrex or Atrazine 4L) | (2 qt) | | |
| (AAtrex Nine-O) | (2.2 lbs) | | |
| **bentazon** | 1 | For use in soybeans or corn. Postemergence when nutsedge shoots are 6 to 8 inches tall. Repeat if new shoots emerge or regrowth occurs. | P11 |
| (Basagran) | (1 qt) | | |
| **EPTC + safener** | 4 to 6 | For use in corn. Preplant incorporation required. | |
| (Eradicane) | (4.75 to 7.3 pts) | | |
| **metolachlor** | 2 to 3 | For use in corn and soybeans. Preplant incorporation gives the best suppression of nutsedge. | |
| (Dual) | (2 to 3 pts) | | |
| **vernolate** | 2 to 3 | For use in soybeans. Preplant incorporation required. | |
| (Vernam 7E) | (2.3 to 3.5 pts) | | |
| (Reward 6E) | (2.6 to 4 pts) | | |

*Reference paragraph number indicates appropriate paragraph in narrative.

**Table P2. Effectiveness of herbicides on perennial weeds.[1,2]**

| Herbicides | Canada thistle | Common milkweed | Field bindweed | Leafy spurge | Perennial sowthistle | Quackgrass | Wirestem muhly | Yellow nutsedge |
|---|---|---|---|---|---|---|---|---|
| atrazine | F | P | P | P | P | G | G | F |
| bentazon (Basagran) | G | N | - | N | - | N | N | G |
| dicamba (Banvel) | G | F | G | F | G | N | N | N |
| fluazifop (Fusilade) | N | N | N | N | N | G | G | N |
| glyphosate (Roundup) | G | F | G | F | G | G | G | F |
| MCPA | F | N | G | N | F | N | N | N |
| picloram (Tordon) | G | G | G | G | G | N | N | F |
| sethoxydim (Poast) | N | N | N | N | N | F | G | N |
| 2,4-D | F | P | G | P | F | N | N | F |

[1]G = Good, F = Fair, P = Poor, N = No control, - = No Data.
[2]Degree of control is often the result of repeated applications.

AGRICULTURAL EXTENSION SERVICE PW-18
UNIVERSITY OF MINNESOTA - U.S. DEPARTMENT OF AGRICULTURE (revised)
INSTITUTE OF AGRICULTURE, FORESTRY AND HOME ECONOMICS
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# Weed and Brush Control Along Roadside, Drainage Ditches, and Other Rights-of-Way

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Weeds and brush along roadsides and rights-of-way must be controlled to protect the large investment in these public utilities and to protect the public who use them. If not controlled, weeds and brush create hazards by restricting visibility at road intersections and on highway warning and marker signs. Brush interferes with telephone and electric power lines. Weeds fill in drainageways and are fire hazards around buildings. Roadsides and rights-of-way are "weed nurseries" which propagate troublesome weeds that then spread to adjoining cropland. In addition, poisonous plants, such as poison ivy, and pollen-bearing plants, such as ragweed, are public health hazards. Noxious weeds and brush in rights-of-way areas must be controlled, but complete vegetation control is usually not desired because of erosion and aesthetic considerations. Periodic applications of 2,4-D or one of the related phenoxy herbicides, or combinations of these, will control most of the troublesome broadleaf weeds and brush without killing the grasses and most of the desireable native broadleafs (forbs). "Spot treatment", or spraying only where patches of noxious weeds and brush occur, is recommended. Grasses and forbs will be favored by the lack of broadleaf competition. Encouragement of the grasses and forbs in these areas provides erosion control and wildlife cover and also improves the appearance of the roadway. Grasses are fibrous rooted and hold the soil better on steep slopes than the tap-rooted broadleaf weeds. Also, most grasses do not grow as tall as broadleaf weeds or brush and require less mowing along roadside shoulders to maintain proper visibility and to minimize excessive drifting of snow onto roadways.

## Methods of Weed and Brush Control

Weeds and small brush can be controlled by periodic mowing. However, two or more mowings are often required to keep weeds down and to prevent weed seed formation. When brush is mowed or cut it quickly resprouts from the base, and becomes thicker. Frequent cutting is necessary for control. With high costs of labor, fuel and machine repairs, mowing of highways and other rights-of-way is extremely expensive. Also, early mowing, before weed seeds mature, is a hazard to nesting birds, their eggs and young birds.

A phenoxy herbicide such as 2,4-D, on the other hand, can be applied from the roadway to adjoining roadsides and ditch banks with little chance of damaging eggs or injuring or killing birds and other wildlife. The herbicide can be applied early in the season (usually sometime in June) in time to prevent the production of weed seeds. A mowing along the edge of the roadside after the nesting season and after grasses are mature is all that is needed to reduce snow pileup in the roadway during the winter months. The use of herbicides on a "spot treatment" basis to control patches of noxious weeds and troublesome brush is less expensive and less time consuming than mowing. Phenoxy herbicides should also be applied in early fall to suppress perennial weed regrowth and weaken the plants for the following year.

Minnesota Noxious Weed Law

Nine weeds are designated as noxious weeds in the state of Minnesota. These weeds are deemed by the Commissioner of Agriculture to be injurious to public health, public roads, crops, livestock or other property. In addition, there are 47 weeds on a secondary weed list in the state. The Minnesota Commissioner of Agriculture may, without further hearing, take a weed or weeds from this secondary list and add it to the noxious weed list on a county basis if: (1) a majority of township boards and city mayors in a county file a petition requesting this addition, (2) the petition is approved by the County Board of Commissioners, and, (3) the Commissioner of Agriculture deems the weed or weeds to be a problem.

The land owner, his agent, or the public official in charge of the land, if it is public land, is responsible to see that noxious weeds growing theron are controlled. Weed control is generally understood to mean preventing weeds from going to seed. Weeds not adequately controlled can be ordered destroyed or eradicated. Destroying or eradicating weeds refers to "complete killing of weeds, both the top growth and underground propagating parts of such weeds". If weeds are not controlled, an official notice may be served by the local weed inspector (township officers or municipal mayor or president), by the County Agricultural Inspector, the district inspector, the state supervisor, or by the State Commissioner of Agriculture. The official notice (Form #1) must contain the following information:

1) Kinds of weeds
2) How to destroy or eradicate these weeds
3) The number of days allowed to comply with the notice
4) Signature of local or County Agricultural Inspector

The nine weeds on the noxious weed list in Minnesota are (1) four herbaceous perennials: Canada thistle, perennial sowthistle, field bindweed, and leafy spurge; (2) three biennials: bull thistle, musk thistle and plumeless thistle; (3) one annual: wild hemp and (4) one woody perennial: poison ivy. In addition to these noxious weeds, the Minnesota Department of Transportation lists ragweed species and common dandelion as additional weeds to be controlled along public highways to improve the roadside environment for human health considerations.

## Selection of Herbicides for Use Along Roadsides, Ditch Banks or other Rights-of-Way (Non-cropland)

1. 2,4-D

2,4-D is a phenoxy or chloro-phenoxy herbicide that is formulated as an amine, oil-soluble amine or low-volatile ester. It is usually the first choice of an herbicide for weed control along rights-of-way because it has little effect on grasses, is effective on a large number of broadleaf weed species and woody plants, is relatively low in cost and is usually readily available. These 2,4-D formulations are low in volatility and are less hazardous to use than the more volatile formulations. Highly volatile formulations, such as butyl ester of 2,4-D, should not be used for right-of-way spraying because vapors may drift and cause injury to nearby desirable plants.

2,4-D will control some woody species such as aspen (poplar), willow and boxelder. However, ash, maple, oak and several other common woody species are resistant to 2,4-D. If these brush species are present, 2,4-D can be mixed with another herbicide, such as 2,4-DP, to control a wide variety of broadleaf weeds and brush. 2,4-D may be used along drainage ditch banks or adjacant to home yards. However, when using 2,4-D or any herbicide used for vegetation control along rights-of-way, precautions must be taken to avoid wind drift to susceptible broadleaf crops, trees, ornamentals or other desireable plants. Drift hazard can be reduced by using low sprayer pressure, preferably no more than 30 to 40 psi (pounds per square inch), using a higher gallonage of water per acre and larger nozzles, by not spraying on windy days, or by using invert emulsions or spray-thickening agents. 2,4-D is rapidly broken down on plant foliage and in the soil, and is not considered a persistant herbicide. For example, 2,4-D may be used on grass pasture if a 7 to 14 day waiting period is observed before grazing dairy cattle on treated areas. Beef cattle should be removed from freshly treated areas for 7 days before slaughter. Check the product label for specific limitations.

2. 2,4-DP

2,4-DP is a phenoxy compound closely related to 2,4-D. 2,4-DP may be used alone, or in combination with 2,4-D to control many 2,4-D resistant broadleaf weed or brush species. 2,4-DP is not cleared for use on pastures, but may be used along drainage ditch banks and on non-cropland areas. The herbicide is not considered persistent and will break down within a few weeks of application.

3. Picloram (Tordon, Amdon)

Picloram is formulated as a 2 lb/gal liquid or as 10 percent pellets. Picloram is a very persistent broadleaf weed and woody plant killer that can be used along roadsides and other rights-of-way to kill phenoxy-resistant weeds or brush. It should not be used along drainage ditches or along streams, lakes, ponds or water runoff areas. Picloram is cleared for spot treatment and broadcast use in grass pastures in Minnesota for the control of 2,4-D resistant broadleaf weeds and brush. Picloram is useful for spot treatment of deep rooted perennials such as leafy spurge, or hard-to-kill woody and fern species such as ash and bracken fern. Because of its longer persistence in soil as compared to 2,4-D and other phenoxy herbicides, and because many broadleaf crops and ornamental plants, including trees and shrubs, are very susceptible to injury from picloram, great care should be taken to avoid drift or misapplication to non-target areas. Picloram has been designated as a restricted use pesticide by the Environmental Protection Agency, and some formulations can only be applied by a certified applicator. Refer to the product label for additional information.

4. MCPA

MCPA is a phenoxy herbicide that is formulated as an amine, an ester or a sodium salt. It is normally not used for roadside or other rights-of-way spraying, but could be used to control certain broadleaf weed or brush species such as spotted knapweed, buttercup, burcucumber, or honeysuckle on which it is more effective than 2,4-D. MCPA is cleared for use on grass pastures with no limitation on use and is non-persistant.

5. MCPP (mecoprop)

MCPP is another phenoxy herbicide closely related to MCPA. MCPP may be used alone or in combination with 2,4-D and/or dicamba (Banvel) for the control of 2,4-D or MCPA resistant broadleaf weeds or brush. MCPP alone, and in various combinations, is cleared for use on lawns and other turf areas, and on non-cropland, but is not yet cleared for use on grass pastures in Minnesota. However, additional clearances are being sought and are expected shortly.

6. Dicamba (Banvel)

Dicamba is labeled for use along roadsides, but because of the great sensitivity of soybeans and most other legume and broadleaf crops and woody plants to dicamba, this herbicide should not be used to spray roadsides and other rights-of-way that are in the vicinity of susceptible field crops, ornamentals, trees and vegetable or fruit crops. Dicamba may be used in combination with 2,4-D to control a broad spectrum of broadleaf weeds and brush where the drift hazard is not a problem. Dicamba is also formulated as a granule, which greatly reduces the drift hazard. However, dicamba is very water soluble, and high rates should not be used along ditches carrying water. Dicamba may be used in grass pastures for broadleaf weed control. Exclude dairy cattle from grazing treated areas for 7 days after application of 1/2 lb or 21 days after application of 1 lb of dicamba. For use of higher rates, see product label.

Note: Before any weeds can be sprayed or otherwise controlled in public waters (rivers, lakes, streams) in the state of Minnesota, a permit must be secured from the Department of Natural Resources, Centennial Office Building, St. Paul, MN.

## Mowing roadsides for forage use

In some areas, farmers wish to mow the roadside once or twice each season and harvest the forage as feed for livestock. This practice is particularly desirable to the landowner on wide roadways and medians where past use of herbicides has eliminated most of the broadleaf weeds and brush. Where this practice is common, highway crews should not spray these areas prior to mowing, or if spraying is necessary, they can spot spray with a herbicide such as 2,4-D so the forage can be harvested for hay after a two week waiting period. If certain poisonous broadleaf weeds such as waterhemlock or bracken fern are present, the farmer should be alerted to the possibility of livestock poisoning from these weeds, and if present, poisonous plants should be controlled with herbicides prior to harvest, or harvesting these areas should be delayed until after chemical treatment and required waiting period. Farmer mowing of the roadway and utilization of this unused resource as livestock feed is looked upon as a benefit to both the farmer and the municipality and is encouraged in some areas. However, regular mowing may destroy the area for wildlife food and cover. Therefore, a system of partial or rotational mowing of an area is desirable, with some sections of roadside being left unmowed each year for wildlife utilization.

## Types of herbicides

Herbicides such as 2,4-D and 2,4-DP are called "selective herbicides" because they will selectively control broadleaf weeds with little or no injury to the grasses. Also, they will selectively control deciduous (broadleaf) woody plants with little or no injury to evergreen (coniferous or needle-bearing) trees. Many selective herbicides, however, may become non-selective if the application rate is increased over the recommended amount.

Another group of herbicides is called "non-selective herbicides". Non-selective herbicides are chemicals that "burn off" or kill all vegetation and may leave the soil non-productive (barren) for a year or more. Some of these complete vegetation control chemicals may be needed around highway guardrails, signs, and around buildings or industrial sites to eliminate fire hazards or to reduce hand labor weed control efforts.

Herbicides may be classed as to their types of applications. Foliarly applied herbicides such as 2,4-D, or paraquat must be applied to the foliage and are not effective if applied to the soil at the rates commonly used. Other herbicides, such as bromacil or simazine, are taken up mainly by plant roots from the soil and do not need to have plant foliage present when the application is made. Herbicides may also be classified as to their mode of action. A contact herbicide, such as paraquat, kills above ground plant tissue only and does not translocate into the root system. 2,4-D is a good example of another type of herbicide - a "translocated herbicide". It moves into the root system from the foliage. These translocated herbicides can kill many perennial weed and brush species. A contact herbicide will not. Herbicides may also be classed as residual and non-residual chemicals. Most herbicides used along roadsides, such as 2,4-D and 2,4-DP are considered to be non-residual chemicals because they break down rapidly and are gone in a few weeks or months. Some herbicides, such as the soil-sterilants already mentioned, are considered residual chemicals and may persist in the area of application for several years.

Selection of the best herbicides or herbicide combination

There are two primary considerations in selecting a herbicide for weed and brush control along highways or other rights-of-way. The first consideration may be safety to non-target plants and other organisms, including the applicator. The second and equally important consideration is performance or effectiveness of the herbicide.

Crops, trees and other broad-leaved plants adjacent to rights-of-way may be injured by herbicides in two main ways, (1) wind drift of the herbicides as it is being applied or (2) vapor drift, by volatility of certain formulations of a herbicide after application, which is evaporation of the herbicide into the air (especially troublesome on hot days) and subsequent drift of these vapors to sensitive plants, which can happen two or three days or more after application. Wind drift can be minimized by using low sprayer pressure, using higher gallonage nozzles, and by not spraying when the wind exceeds 5 to 10 mile per hour. In addition, invert emulsions (water-in-oil droplets rather than oil-in-water), which have the consistency of mayonnaise, can be used to reduce or prevent wind drift. Spray thickening agents of various kinds can also be used to reduce drift potential. Volatility can be minimized by choosing low-volatile herbicides or herbicide formulations. Among the herbicides, dicamba (Banvel) is the cause for most concern. It should be used only when sensitive plants are not in the vicinity. Among formulations, high volatile esters of 2,4-D should not be used because of the possiblity of vapor drift. Safety to the applicator may be accomplished by strict adherence to label precautions and safe equipment operating procedures.

Effective herbicide performance is dependent on proper identification of the weed or brush species to be controlled and the careful selection of herbicides or herbicide combinations that are most effective in controlling those species. Refer to "Systemic Herbicides for Weed Control", No. AD-BU-2281, to herbicide labels or to this publication (Table 1) to determine the best herbicide for a particular weed problem.

Time of application of herbicides

For best results, foliarly applied herbicides such as 2,4-D should be applied when perennial weeds are 6 to 8 inches tall and up to bud stage. Brush should be fully leaved out and growing rapidly. Perennial weeds should normally not be sprayed early in the spring when they are 2 to 3 inches tall or less because not enough spray will usually be retained on the foliage to kill the root. Also, the early spring flow of nutrients from root to shoot to support early spring top growth limits herbicide movement from shoot to root and results in poor control. Herbicides may also be applied in the fall until frost kills the leaves, but if perennial weeds are mature or nearing maturity and seed production has occurred, it is more effective to mow perennial weeds and then spray the regrowth when it is 6 to 8 inches tall. Application of herbicides in the fall, when crops and gardens are nearing maturity, will often result in much less injury to non-target plants.

Summary of principal considerations for spraying rights-of-way with herbicides

1. Identify weeds and brush to be controlled.
2. Select best herbicide or combination of herbicides for control. (Tables 1,2,3 or 4)
3. Select a low-volatile ester, amine or formulation of 2,4-D to reduce or eliminate the danger of vapor drift.
4. Calibrate the sprayer to determine output per acre or per unit area (using linear feet of miles of roadway sprayed x width of area sprayed and measurement of water used to spray an area).
5. Put the right amount of herbicide concentrate in the tank for each tankful.
6. Use low pressure (no more than 30 to 50 psi) to minimize spray drift.
7. Don't spray when the wind speed is excessive (preferably not over 5 miles per hour). Use an invert emulsion or spray thickening agent to reduce drift, if necessary. Avoid direct spraying of herbicides onto non-target plants.
8. Spray early in the season (usually in June) to perennial weeds in the bud stage, to brush that is fully leaved out, or spray in the fall when perennial weeds have new short growth of 8 inches or more.
9. Prevent herbicide spills on clothing or skin, follow safety precautions listed on label.
10. Do not use picloram (Tordan) or high rates of dicamba (Banvel) along drainage or irrigation ditches or along streams, lakes, or other open water.
11. Keep a complete record of spraying operations, recording chemical used, weather and wind conditions at time of spraying, date sprayed, etc.

Application of herbicides along rights-of-way

There are two principal methods of herbicide application used along rights-of-way. First, and perhaps the most common, is the use of a broad jet or gun type nozzle that makes use of considerable pressure, usually more than 50 pounds per square inch, to direct the spray at the weeds and brush to be controlled. This method utilizes relatively large gallonages of 50 to 200 gallons of water per acre and wets the foliage to the point of run-off. The spray is prepared by mixing the desired quantity of herbicide concentrate in the estimated gallonage of spray to be applied. A more accurate estimation can be made of sprayer output by measuring a roadside or right-of-way area, then computing the acreage involved (43,560 sq ft = 1 acre), spraying it with water only, and determining the gallonage applied per acre. Then the proper amount of herbicide concentrate can be put in the tank for the size of batch being mixed.

The second method of spraying rights-of-way is using a boom on either ground or aerial equipment. The boom type sprayer delivers a much more accurate and uniform spray pattern, gives better coverage of plant foliage, and can utilize smaller gallonages of water (as little as 15 to 20 gallons per acre will give adequate coverage in many cases). When using ground equipment, the height of the boom must be adjusted to give a uniform spray pattern, and all nozzles should be calibrated to make sure they are delivering the same volume of spray. The sprayer should be calibrated by determining sprayer output per acre or by linear feet of right-of-way sprayed and then putting the proper amount of herbicide spray concentrate in the tank for the gallonage of spray being delivered per unit area.

Right-of-way spraying examples

1. Suppose you are to operate a broadjet sprayer to apply herbicides along a road right-of-way. There is mixed hardwood brush, Canada thistle and other broad-leaved weeds to be controlled. You have been asked to apply a mixture of 2,4-D and 2,4-DP at 1 lb of each component per acre. The label on the product stated that there are 2 lbs of 2,4-D and 2 lbs of 2,4-DP acid equivalent per gallon. The label also states that the material is a low-volatile ester formulation and an emulsifiable concentrate in liquid form.

Question 1 - How much product, as it comes from the container, should you apply per acre?____________________

2. You wish to calibrate your sprayer to determine approximate sprayer output per acre. There is a 320 gallon tank on the sprayer graduated in 10 gallon increments. You wish to mix a full batch of spray each time you fill. You fill the spray tank with water in preparation for a test run. You measure off a distance of 330 feet on the roadway and determine that the width of the area to be sprayed on each side of the roadway is approximately one rod (16.5 feet). From a "running start" at a sprayer pressure of 40 pounds per square inch (psi) and at uniform speed, spray the foliage on one side of the roadway for the 330 feet distance just as you would if you were using the herbicide. Spray to the point of runoff, moving the nozzle gun smoothly and uniformly to achieve good coverage of the weeds and brush to be controlled. Then you refill the tank, and by measuring the amount needed you determine that you used 10 gallons of water to cover the test area. There are 43,560 square feet/acre.

Question 2 - What fraction of an acre did you spray?_______________

Question 3 - What gallonage are you applying per acre?_______________

Question 4 - How many acres can you spray per tankful?_______________
There are 5,280 feet per mile.

Question 5 - How many miles of roadway (spraying both sides) can you spray per tankful?____________________

Answers: 1) 1/2 gallon; 2) 1/8 acre; 3) 80 gpa; 4) 4 acres; 5) 1 mile.

Table 1. Susceptibility of noxious and other undesirable weeds and brush to phenoxy herbicides 1/

| Plant | Life cycle | 2,4-D | 2,4-DP | Dicamba | Picloram |
|---|---|---|---|---|---|
| Field bindweed | Perennial | Fair | Fair | Good | Good |
| Leafy spurge | Perennial | Poor | Fair | Fair | Good |
| Canada thistle | Perennial | Fair | Fair | Excellent | Excellent |
| Perennial sowthistle | Perennial | Fair | Fair | Good | Good |
| Bull thistle | Biennial | Excellent | Excellent | Excellent | Excellent |
| Musk thistle | Biennial | Good | Good | Good | Excellent |
| Plumeless thistle | Biennial | Good | Good | Good | Excellent |
| Hemp | Annual | Good | Good | Good | Excellent |
| Poison ivy | Woody perennial | Fair | Good | Good | Good |
| Common ragweed | Annual | Excellent | Excellent | Excellent | Excellent |
| Giant ragweed | Annual | Excellent | Excellent | Excellent | Excellent |
| Common dandelion | Perennial | Excellent | Excellent | Excellent | Excellent |
| Ground Ivy (Creeping Charlie) | Perennial | Fair | Good | Good | Excellent |
| Common chickweed | Annual | Fair | Good | Excellent | Excellent |
| Waterhemlock | Perennial | Good | Good | Excellent | Excellent |
| Ash | Woody perennial | None | Poor | Poor | Fair |
| Boxelder | Woody perennial | Good | Good | Good | Fair |
| Buckbrush | Woody perennial | Good | Good | Poor | Good |
| Elm | Woody perennial | Poor | Fair | Fair | Good |
| Aspen (poplar) | Woody perennial | Fair | Fair-Good | Fair | Good |
| Oak | Woody perennial | Poor | Fair-Good | Poor | Fair |
| Willow | Woody perennial | Good | Good | Fair | Good |
| Maple | Woody perennial | Poor | Fair | Poor | Good |

1/Adapted from Farmer's Bulletin No. 2183 USDA, Using Phenoxy Herbicides Effectively, and from research trials.

Table 2. Summary of herbicides for broadleaf weed and brush control on roadsides and drainage ditch banks.

| Chemical | lb/A | Time of application | Precautions |
|---|---|---|---|
| For thistles and other broadleaf weeds | | | |
| 2,4-D amine or L.V. ester | 2 | When perennial broadleaf weeds are 6 to 10 inches tall and before bud stage or in the fall on active new weed growth. | Use low pressure (30-40 psi). Avoid drift. 2,4-D may be used along drainage ditches. Glean should not be used near water or drainage ditches. |
| Chlorsulfuron (Glean) | 1/4 oz-2 oz/acre | | |
| For broadleaf weeds and 2,4-D resistant brush | | | |
| 2,4-DP | 2 | When brush is fully leaved out and before bud stage of broadleaf weeds or in the fall on active new weed growth. | Avoid drift. May be used along drainage ditch banks. |
| 2,4-D + 2,4-DP | 1 + 1 | | |
| MCPP (mecoprop) | 2 | | |
| 2,4-D + MCPP + dicamba (Trimec-352) | 2 + 1 + 0.2 | | |
| 2,4-D + MCPP + dicamba (Trimac 4-41) | 1.88 + 2 + 0.5 | | |
| For spot treatment of 2,4-D resistant broadleaf weeds or brush | | | |
| Picloram (Tordon, Amdon) | 1/2 to 1 | When brush is fully leaved out and before bud stage of broadleaf weeds or in the fall on active new weed growth. | Picloram is a persistent and water soluble herbicide. (Restricted use material.) Do not use these herbicides along drainage ditch banks or along streams, lakes or water supplies. Avoid drift to non-target broadleaf plants. |
| Picloram + 2,4-D (Amdon 101 Tordon 101) | 1/2 + 1 | | |
| Dicamba + 2,4-D (Banvel 720) | 1 + 2 | | |
| Brush control | | | |
| Fosamine (Krenite) | 6 to 12 | Apply during the 2 month period prior to fall leaf coloration. | May be used on drainage ditch banks. |

Table 3. Chemicals for temporary or short-term vegetation control (non-cropland, fence rows, highway guardrails, parking lots, building sites, etc.

| Grasses and cattails | Broadleafs | Grasses and broadleafs |
|---|---|---|
| dalapon (Dowpon M) | 2,4-D | paraquat |
| TCA | 2,4-DP | amitrole |
| dalapon and TCA (Dowpon C) | MCPP | amitrole - T |
| | picloram (Tordon, Amdon) | glyphosate (Roundup) |
| | MCPA | ammonium-sulfamate (Ammate) |
| | dicamba (Banvel) | |
| | 2,4,5,-T or Silvex | |

1 Restricted use herbicide. May be applied only by a certified applicator.

2 Water soluble compounds. Use with caution around desirable broadleaf plants, trees and shrubs.

3 May still be used on certain non-cropland sites such as airports, fencelines not adjacent to pasture, lumber yards, refineries, storage areas, tank farms or industrial sites (not otherwise included in suspended uses).

Table 4. Chemicals for long-term vegetation control (non-selective) (non-cropland, fence rows, highway guardrails, parking lots, building sites, etc.)

Broadleaf and Grass Control

sulfomethureon methyl (Oust)

*bromacil (Hyvar-X, Hyvar-XL)

diuron (Karmex)

diuron/bromacil (Krovar, liquid; Bromex granules)

simazine (Princep)

atrazine (AAtrex, atrazine)

prometone (Pramitol)

simazine and amitrol (Amizine)

*AMS (Ammonium sulfamate) Ammate

borates

sodium chlorate

borax and 2,4-D (D.B. Granular)

*hexazinone (Velpar)

*tebuthiuron (Spike - available as wettable powder or pellets)

chlorosulfuron (Telar)

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* May also be used for spot treatment of brush species. However, these materials must be used with caution because the roots of desirable trees or shrubs may pick up and translocate these materials.

Table 5. Cut stump treatment of brush and trees.

| |
|---|
| 2,4-D + 2,4-DP + penetrating agent (Weedone CB - apply undiluted |
| Dicamba (Banvel CST) - apply undiluted |
| Dicamba + 2,4-D + oil or diesel fuel as carrier |
| Picloram (Tordon 101R, Tordon RTU) - apply undiluted |
| Ammonium sulfamate (Ammate) - apply as crystals or water base spray |
| Triclopyr (Garlon) - apply undiluted or mix with diesel fuel |